UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: December 12, 2000

TO : The Commission
Sadye E. Dunn, Secretary

THROUGH: Michael S. Solender, General Counsel MSS
Stephen Lemberg, Assistant General Counsel for Regulatory Affairs

FROM : Lowell F. Martin, Attorney, GCRA (ext. 2217) LFM.

SUBJECT : Petition HP 00-03 Requesting a Ban of Candle Wicks Containing Lead and of Candles Containing Such Wicks

VOTE SHEET

The attached staff briefing package recommends that the Commission: (1) grant Petition No. HP 00-03 requesting a ban of candle wicks containing lead and of candles containing such wicks, and (2) proceed to issue an advance notice of proposed rulemaking (ANPR) to commence a rulemaking under the Federal Hazardous Substances Act (FHSA) to do so. Submissions received from Public Citizen and jointly from the National Apartment Association and the National Multi Housing Council requesting such a ban are docketed collectively as Petition No. HP 00-03. Tab G of the package is a draft Federal Register notice that would commence a rulemaking proceeding by issuing an ANPR.

Please indicate your vote on the following options.

I. GRANT THE PETITION AND APPROVE THE FEDERAL REGISTER NOTICE AS DRAFTED.

______________________ ______________
(Signature) (Date)

II. GRANT THE PETITION AND APPROVE THE DRAFT FEDERAL REGISTER NOTICE WITH THE FOLLOWING CHANGES (PLEASE SPECIFY).

____

____

______________________ ______________
(Signature) (Date)

CPSA 6 (b)(1) Cleared 12/13/00
____ No Mfrs/PrvtLblrs or Products Identified
____ Excepted by
____ Firms Notified,

NOTE: This document has not been reviewed or accepted by the Commission.
Initial ____ Date 12/13/00

III. DENY THE PETITION AND DIRECT STAFF TO PREPARE A LETTER OF DENIAL FOR COMMISSION CONSIDERATION.

____________________________ ______________

(Signature) (Date)

IV. TAKE OTHER ACTION (PLEASE SPECIFY).

(Signature) (Date)

Attachment

Briefing Package

Petition No. HP-00-3, Request to Ban Candles with Lead-containing Wicks and Wicks Sold for Candle-making that Contain Lead

For Information Contact:

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Executive Summary

On February 24, 2000, the U.S. Consumer Product Safety Commission (CPSC) received a petition from Public Citizen, requesting that the Commission ban candles with lead-containing wicks and wicks sold for candle-making that contain lead (Tab A). On February 29, 2000, CPSC received a similar petition from the National Apartment Association and the National Multi Housing Council. These petitions were docketed collectively under the Federal Hazardous Substances Act (FHSA) (Petition No. HP 00-3) on March 17, 2000.

According to Public Citizen, about 3% of the candles they purchased in retail stores in the Washington, D.C.-Baltimore area contained lead in their wicks (about 10% of the metal-cored wick candles tested).

The staff found that the industry did not adhere to its 1974 voluntary agreement to discontinue the use of lead-cored wicks. Recently, U.S. candle and wick manufacturers and retailers again agreed to stop the production and sale of lead-cored wicks and candles with lead-cored wicks. Currently, there are no standards in place that address this issue.

CPSC staff and other researchers have shown that candles containing lead-cored wicks may emit relatively large amounts of lead into the air during candle burning. Candles analyzed by CPSC staff and other researchers emitted lead up to 2,200 micrograms per hour (µg/hour) during burning. The data show that the amount of lead released into the air during burning of lead-cored wick candles varied greatly among the tested candles. This was true even among samples of several identical candles. The reasons for this variability are not known. Thus, it is not possible to predict whether a lead-containing candle wick will emit small amounts or relatively large amounts of lead during burning.

Under certain expected use conditions, the emitted lead presents a risk to consumers from exposure through inhalation of airborne lead. Some of the emitted lead may also deposit onto surfaces in the room. This deposited lead could remain accessible to a child for an extended period of time, where exposures would occur through direct mouthing of surfaces or objects or by hand-to-mouth contact.

The amount of lead emitted from lead-containing wicks during candle burning does not correlate well with the lead content of the wicks and therefore cannot be predicted by the lead content. However, the lead emissions from some candles that used lead alloys in their wicks exceeded 430 µg/hr, the level that CPSC staff determined would cause excessive lead exposure in children. Because of the unpredictability of the actual lead emissions level from a given candle and the likelihood that children would be exposed in some circumstances to excessive lead emitted from lead-cored wick candles, the staff recommends a ban on lead-cored wicks.

Alternatives to use of lead alloys in candle wicks include zinc and tin alloys. These substitute alloys may contain unintentional trace amounts of lead. However, test data indicate that burning candles with metal-cored wicks with lead concentrations of 0.06% or less by weight do not result in detectable air emissions. Accordingly, for purposes of this rulemaking, CPSC staff recommends that a lead-cored wick be defined as a wick containing a metal core with greater than 0.06% lead by weight in the metal.

The staff believes that a mandatory standard is warranted because 1) lead exposure from burning candles with lead-cored wicks can present a risk of lead poisoning; 2) it is not possible to predict lead exposure from the lead content of the wick; 3) substitutes for lead-cored wicks are available and currently in use; 4) candle wicks with metal cores containing 0.06% lead or less are unlikely to release hazardous amounts of lead; and 5) past experience indicates that voluntary industry agreements are unlikely to be effective over time and mandatory standards are more likely to be followed.

A mandatory standard would 1) apply to all domestic and imported candle and wick products regardless of a company's membership in a trade organization or knowledge of ASTM standards; 2) deter manufacturers from making non-conforming wicks or candles and enable the staff to seek civil penalties for violations; 3) increase compliance by retailers and distributors who often require that products meet applicable federal standards; and 4) prevent non-complying products from entering the U.S. through cooperative efforts with the U.S. Customs Service.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: DEC 12 2000

TO : The Commission
Sadye E. Dunn, Secretary

THROUGH : Michael Solender, General Counsel, Office of the General Counsel MS/

THROUGH : Pamela Gilbert, Executive Director, Office of the Executive Director

FROM : /s/ Ronald L. Medford, Assistant Executive Director, Office of Hazard Identification and Reduction je
Kristina M. Hatlelid, Ph.D., M.P.H., Toxicologist, Directorate for Health Sciences KH

SUBJECT : Petition HP 00-3 to Ban Lead-cored Candle Wicks

This briefing package presents the staff analysis of the available data on lead-cored candle wicks in response to a petition to ban these products and provides a draft advance notice of proposed rulemaking (ANPR) if the Commission decides to vote to publish the ANPR.

Petition Information

On February 24, 2000, the U.S. Consumer Product Safety Commission (CPSC) received a petition from Howard L. Sobel, Sidney M. Wolfe, and Peter Lurie of Public Citizen, requesting that the Commission ban candles with lead-containing wicks and wicks sold for candle-making that contain lead (Tab A). On February 29, 2000, CPSC received a similar petition from the National Apartment Association and the National Multi Housing Council. These petitions were docketed collectively under the Federal Hazardous Substances Act (FHSA) (Petition No. HP 00-3) on March 17, 2000.

Public Citizen surveyed 285 candles from 12 stores in the Baltimore-Washington, DC area. They found 9 candles (3% of the total sample) that had wicks containing between 33% and 85% lead by weight. They estimated that approximately 12 million candles sold in 1999 contained lead.

Public Citizen estimated that when burned for 3 hours daily, each of these candles would emit an amount of lead that, when inhaled from the air, they consider to be hazardous to fetuses, infants, and young children. They also estimated that some of the lead would deposit onto floors and surfaces from the air, where it would become an ingestion hazard.

Public Citizen argues that labeling will not adequately protect candle users since the at-risk population (fetuses, infants, and young children) does not choose to burn these products. They also maintain that the failure of a previous industry voluntary agreement in 1974 necessitates a ban of these products.

Background

Lead-cored wicks are candle wicks with a metal thread in the center made of lead or lead alloy. The metal core is used to provide structural rigidity to the wick, *i.e.*, to keep the wick straight during candle production, and to provide an upright wick during burning.

As a lead-cored wick candle burns, some of the lead may vaporize and be released into the air. This airborne lead may be inhaled. Some of this lead may deposit onto floors, furniture, and other surfaces in the room where children may be exposed to it. One cannot tell by looking at the wick core if it is made of lead, and there is no simple way for a consumer to determine its lead content. The presence of lead in a wick can be determined only by laboratory analysis.

Similarly, one cannot tell if lead is being released from a burning candle by observing smoke or soot; nor can one tell that lead is not being released by the lack of visible emissions. Determination of lead in room air or on surfaces must be done by professionals.

The potential for serious injury from lead-cored wick candles was previously considered by the Commission in 1973 as described below. In the 27 years since that time, the scientific community has recognized that lead is more toxic than previously considered and that serious injury to children may occur from exposures to lead at levels that are much lower than previously thought.

Requirements under the FHSA

Under section 2(f) of the FHSA, 15 U.S.C. section 1261(f), household products with quantities of lead that may cause substantial illness if children ingest or inhale them during or as a result of reasonably foreseeable conditions of handling or use are "hazardous substances." A household product that creates such a risk of injury because it contains lead (that is, it is a "hazardous substance") requires cautionary labeling under the Act. 15 U.S.C. 1261(p). A toy or other article intended for use by children that contains a hazardous amount of lead that is accessible to children under the conditions described above is declared to be a "banned hazardous substance." 15 U.S.C. § 1261(q)(1)(A).

Section 2(q)(1)(B) of the FHSA provides the authority to ban a household product that is a hazardous substance if the Commission finds that, in spite of any cautionary labeling, the product presents a hazard such that protection of public health and safety can be adequately served only by keeping the product out of the channels of interstate commerce. 15 U.S.C. § 1261(q)(1)(B).

Previous Commission Activity

The Commission previously considered whether to ban lead-cored wicks. In 1973, the Commission was petitioned by Public Citizen Health Research Group to ban immediately candles with lead-cored wicks because they constituted an imminent hazard for the purposes of § 2(q)(2) of the FHSA. The Commission denied the petition. At that time, the staff indicated that research on such products would continue.

Voluntary Standards

In 1974, the Candle Manufacturers Association industry group submitted a statement informing the Commission of an agreement among candle manufacturers to convert to substitutes for lead-cored wicks in candles by the end of the third quarter 1974. They also agreed not to import lead-cored wick candles. Further, the major American wick manufacturer at that time agreed to discontinue the production of lead-cored wicks.

Despite this agreement, some wick manufacturers resumed producing lead-cored wicks and some candle manufacturers resumed producing and importing lead-cored wick candles after 1974.

Currently, there are no applicable standards in place that address the lead content of candle wicks. In May 2000, a task group for candle wicks was formed under the ASTM F15.45 Candle Products subcommittee to develop a standard to address the lead content of lead in candle wicks. The task group is in the process of developing a standard for lead content of metal-cored wicks.

Other Standards

In September 1999, in response to a study of several candles imported from China, the Minister for Financial Services and Regulation of Australia banned the sale of candles with wicks that contain lead under the Trade Practices Act of 1974. The ban remains in effect for 18 months unless revoked before the end of that time or otherwise made the subject of a permanent ban. In June 2000, the Minister of Consumer Affairs in New Zealand issued a similar order that bans the sale or importation of candles with lead in their wicks under the Fair Trading Act. This order also is in effect for 18 months unless a further order is made. Neither of these orders refers to a maximum allowable level of lead; both appear to cover any level of lead in the wicks.

The Commission staff is not aware of any other state, foreign, international, voluntary, or other standard that addresses the use of lead-cored wicks in candles.

Hazard

While excess lead exposure can cause adverse health effects in adults, children are particularly susceptible to the toxic effects of lead. The scientific community generally recognizes a level of 10 micrograms of lead per deciliter of blood (10 µg/dL) as a threshold level of concern with respect to lead poisoning in children (CDC, 1991). The most current national survey shows that nearly 1 million children have elevated blood lead levels (greater than 10 µg/dL). This figure represents approximately 4.4% of children under 6 years of age (CDC, 1997).

The adverse health effects of lead poisoning in children are well-documented and may have long-lasting or permanent consequences. These effects include neurological damage, delayed mental and physical development, attention and learning deficiencies, and hearing problems. Because lead accumulates in the body, even exposures to small amounts of lead can contribute to the overall level of lead in the blood and to the subsequent risk of adverse health effects. Therefore, any unnecessary exposure of children to lead should be avoided.

In 1998, the Commission issued guidance to manufacturers, importers, distributors, and retailers to help reduce the risk of hazardous exposure to lead from consumer products (CPSC, 1998). This guidance highlights certain obligations under the FHSA, 15 U.S.C. §§ 1261-1278, describes the risks to young children associated with exposure to lead, and requests manufacturers to eliminate the use of lead in consumer products.

Paint and similar surface coatings containing lead have historically been the most commonly recognized sources of lead poisoning. The Commission has, by regulation, banned paint and other similar surface coatings that contain more than 0.06% lead ("lead-containing paint"), toys and other articles intended for use by children that bear lead-containing paint, and furniture articles for consumer use that bear lead-containing paint. 16 CFR Part 1303.

In many cases, however, the source of lead exposure cannot be readily identified. For example, one study found that despite extensive environmental investigation, the source of lead exposure was not identified in 18% of infants and 9% of toddlers with elevated blood lead levels (Shannon and Graef, 1992).

It is possible that some of these lead poisoning cases (*i.e.*, those that are not identified as related to paint or environmental sources such as lead-contaminated soil) are due to exposure to lead from consumer products. The Commission staff has identified a number of disparate products—some intended for use by children and others simply used in or around the household or in recreation—that present a risk of lead poisoning from sources other than paint. These products included crayons, figurines used as game pieces, children's jewelry, and imported vinyl miniblinds (CPSC, 1996).

Young children are most commonly exposed to lead in consumer products from the direct mouthing of objects or from handling such objects and subsequent hand-to-mouth activity. In the case of lead-cored wick candles, children may be exposed to the airborne lead by inhaling it. They may also be exposed to the lead that deposits from the air onto the floor and other surfaces in the room through direct mouthing of contaminated objects and surfaces or from handling such objects and surfaces and subsequent hand-to-mouth activity.

To prevent children from exceeding the 10 µg/dl blood lead level (BLL) of concern, CPSC staff seeks to limit chronic inhalation or ingestion of lead from consumer products to less than 15 µg of lead per day.

Assuming children are in the room 80% of the day, the 15 µg/day exposure would be reached if the 24-hour average lead concentration in air were about 2.8 µg/m^3. Using a standard air concentration model and assuming a closed, 15 ft. by 15 ft. room with an 8 ft. ceiling (51 m^3) with 0.5 air exchanges per hour, a candle burning for 4 hours/day for 15-30 days would contribute to excess lead exposure for children in the room (*i.e.*, 15 µg/day) if it emitted 430 µg lead per hour (Tab B).

The amount of lead released from a lead-cored wick candle is variable and depends on a number of factors including the wick size and other wick characteristics, wax characteristics, and burning conditions. Investigations by the CPSC Laboratory and other laboratories indicate that lead-cored wick candles can emit up to about 2,200 µg of lead per hour during candle burning (Tab B). Therefore, under certain expected use conditions, the staff believes that lead emissions from candles could present a risk to consumers of substantial illness through inhalation of airborne lead and through contact with lead deposited onto surfaces in the room.

The amount of lead emitted from lead-containing wicks during candle burning does not correlate well with the lead content of the wicks and therefore cannot be predicted by the lead content. However, the lead emissions from some candles that used lead alloys in their wicks exceeded 430 µg/hr, the level that CPSC staff determined would cause excessive lead exposure in children. Because of the unpredictability of the actual lead emissions level from a given candle and the likelihood that children would be exposed in some circumstances to excessive lead emitted from lead-cored wick candles, the staff recommends a ban on lead-cored wicks.

Alternatives to use of lead alloys in candle wicks include zinc and tin alloys. These substitute alloys may contain unintentional trace amounts of lead. However, test data indicate that burning candles with metal-cored wicks with lead concentrations of 0.06% or less by weight do not result in detectable air emissions. Accordingly, for purposes of this rulemaking, CPSC staff recommends that a lead-cored wick be defined as a wick containing a metal core with greater than 0.06% lead by weight in the metal.

Consumers may also be exposed to zinc or tin released from burning candles with zinc- or tin-cored wicks (Tab B). CPSC staff has measured zinc releases from burning zinc-cored wick candles, but the levels were lower than the levels observed to cause illness in humans or experimental animals exposed to zinc fume or dust. Tin emissions from candles have not been determined, but the long-term exposures to high levels of dust experienced by workers are not expected for consumers who burn candles. Further, the lungs of workers exposed to relatively large amounts of tin compounds did not show tissue reactions, and the workers experienced no impairment of pulmonary function or systemic disease. Therefore, the staff has no basis to believe that zinc or tin emissions from burning candles with metal-cored wicks represent a hazardous exposure to these metals.

Labeling Issues

Cautionary labeling becomes an important issue when discussing a possible ban of a substance under the FHSA. To ban lead-cored wicks, the Commission would have to show that the public can be protected adequately only by eliminating the product.

A CPSC Human Factors staff analysis concluded that labeling is not an acceptable strategy for protecting vulnerable populations from lead poisoning that may be caused by burning candles with lead-cored wicks. This information is discussed below and detailed at Tab C.

The analysis showed that since lead is emitted from a candle when the wick is lit, no label or subsequent action by the consumer would prevent the release of lead into the air when the candle is used as intended. Further, it is not realistic to expect a candle to be used for decorative purposes only and not be lit.

Economic Information

The staff evaluated available information on the candle and candle wick market. This information is discussed below and detailed at Tab D.

Product Information

Candle wicks are of three general types, and are chosen for specific characteristics and applications. Flat braided wicks are made of cotton and are used in taper candles; square wicks are used in beeswax candles and candles that develop small wax pools when burning. The third type of wick is the cored wick, which is used in votives, pillars, tealights, and other container candles and provides rigidity in candles that develop deep wax pools. Wick cores may be composed of cotton, paper, polypropylene, or metal, such as lead, zinc, or tin.

Market Information

The precise number of U.S. candle manufacturers is not known. The InfoUSA database of U.S. manufacturers lists 355 companies as "candle manufacturers." The National Candle Association (NCA) and the U.S. International Trade Commission state that there are over 200 commercial, institutional and religious manufacturers of candles in the U.S. They also indicate that there are many small craft producers of candles. About 70 candle manufacturing firms are members of the NCA. Of these, nine are foreign firms, mostly from Canada and Mexico.

Most candle companies are small businesses. Of the 355 firms identified as candle manufacturers by InfoUSA, all but two firms had fewer than 500 employees, the U.S. Small Business Administration's threshold for defining a business as small. Most firms were much smaller than the threshold limit. In fact, 188 (53%) had fewer than 5 employees.

Three domestic producers of candle wicks have been identified. The leading producer accounts for the majority of candle wicks used by the U.S. candle industry. Additionally, three foreign wick producers are members of the NCA; two are based in Germany, and one in Brazil.

Retail sales of candles for 1999 are estimated to be $2.3 billion, and are expected to rise to about $3.2 billion in 2001. U.S. imports of candles in 1999 amounted to about $484 million, about half from the Far East, about one third from the Americas (mostly Canada and Mexico), and less than 10 percent from Europe and Great Britain. No specific information is available on domestic shipments or sales of candle wicks since they are classified with other textile products such as window blind cords, ropes, and decorative trims.

The lead-cored wick is one example of a cored wick. Other cored wicks use cotton, paper, polypropylene, zinc, or tin. All of these wicks serve to provide rigidity to the wick during candle production and burning.

Cored wicks (*i.e.*, paper, cotton, and metal-cored wicks) make up about 40% of candle wicks. The market breakdown by type of materials used in cored wicks is not precisely known at this time, but the leading U.S. wick manufacturer reported that about 20% of their wicks used zinc or tin cores, and prior to discontinuing their use of lead in 1998, about 1% of the wicks produced by them in the 1990s had lead cores. The remainder of their wicks used non-metal materials.

According to the petitioner, Public Citizen, about 30% of candles they purchased in retail stores in the Washington, D.C.-Baltimore area had metal-cored wicks. About 10% of the metal-cored wicks contained lead (3% of the candles tested).

Commission Staff Activities

In December 1999, CPSC staff met with representatives of the National Candle Association (NCA). At this meeting, the CPSC staff discussed the candle industry and its use of lead-cored wicks. The staff requested that the Association actively discourage the production of lead-cored wicks and eliminate their use in the manufacturing of candles by its member firms.

In addition, CPSC staff sent letters to hundreds of domestic candle and wick manufacturers and retailers, as well as to retail trade associations and the Ambassador of China. These letters highlighted the CPSC's "Guidance Policy for Lead (Pb) in Consumer Products" and requested that all companies eliminate the manufacture, import, and sale of lead-cored wicks in the U.S.

To date, the responses to these letters indicate that 1) many companies have already taken steps to ensure that lead is not a component in their candle wicks, and 2) those companies that only recently became aware of this issue will take steps to eliminate lead from their products if it is there.

Public Comments

The CPSC received public comments and information from 142 consumers and organizations in response to the Federal Register Notice for Petition HP 00-3 (65 FR 19742, April 12, 2000). A discussion of the issues raised by commenters and staff responses to them is summarized below and detailed at Tab E. The index of the public comments is in Tab F.

Mandatory ban: More than one in five commenters, representing both public health professionals and private citizens, reiterated the position of the petitioners that the voluntary agreement drafted by the industry in 1974 did not effectively stop the manufacture or sale of lead-cored wicks in the U.S.

Response: The staff agrees with the commenters that the industry did not adhere to the 1974 voluntary agreement and agrees that a mandatory standard is necessary.

ASTM: Co-petitioners National Apartment Association and National Multi Housing Council believe the ASTM standards process is too slow to address the potential for adverse health effects from lead exposure from lead-cored wick candles. They also do not believe the industry-dominated task group is able to establish an appropriate health-protective standard. The Alliance to End Childhood Lead Poisoning questions whether the ASTM can adapt a standard that would be protective of health and that would be widely recognized and enforceable.

Response: If the Commission proceeds to issue a mandatory ban on lead-cored wicks in candles, and an applicable voluntary standard has been adopted and implemented, the Commission could not issue the ban unless it found either that compliance with the voluntary standard would not adequately reduce the risk or that it is unlikely that there will be substantial compliance with the voluntary standard. 15 U.S.C. § 1262(I)(2)(A).

Currently, there are no applicable standards in place that address the lead content of candle wicks. In May 2000, a task group for candle wicks was formed under the ASTM F15.45 Candle Products subcommittee to develop a standard to address the lead content of lead in candle wicks. The task group is in the process of developing a standard for lead content of metal-cored wicks.

The staff believes that a mandatory standard is needed in part because it would apply to all domestic and imported candle and wick products regardless of a company's membership in a trade organization or knowledge of ASTM standards (*e.g.*, small businesses).

Recall candles with lead-cored wicks: About one in five commenters, mostly private citizens, reiterated the request of the petitioners for a recall of candles with lead-cored wicks.

Response: The recall requested by Public Citizen would not require rulemaking to implement. Therefore, the Commission's procedural rules for petitions, at 16 C.F.R. § 1051, do not apply to that request, and the request for recalls was not docketed as part of the petition. The request for recalls may be considered separately by the Office of Compliance.

Toxicity of lead: The harmful effects of lead exposure in children were reiterated by a number of commenters. Several commenters emphasized that lead is not a necessary component of candles and that the use of lead in candle wicks may lead to a hazardous lead exposure from burning them.

Response: The adverse health effects of lead exposure in children are well-documented and may have long-lasting or permanent consequences. The staff analysis indicates that exposure to lead emissions from candles under certain conditions contributes to excess lead exposure.

Further, since most candles do not contain lead-cored wicks, the staff believes that the use of lead in candle wicks is not required for wick or candle manufacture.

Necessity of candles: While several commenters claim that candles are simply decorative or a luxury item and are not necessary to own or use, at least one citizen emphasized that in rural areas with frequent power outages, candles are a necessity.

Response: The staff acknowledges that consumers purchase and use candles for many reasons. The likelihood that a particular lead-cored wick candle will cause excessive lead exposure to consumers does not depend on the circumstances of its purchase. Since lead-cored wick candles have been shown to present a risk to consumers from exposure to lead, the staff recommends that metal-cored wicks contain no more than 0.06% lead by weight in the metal.

Substitute materials: Several commenters claim that many wick manufacturers produce wicks without using lead and that many candle makers produce candles that do not use lead-cored wicks. At least one commenter pointed out that other countries have issued notices that ban the import and sale of lead-containing wicks.

Response: The information developed by CPSC staff supports the claim that alternatives to the use of lead cored-wicks are available. From the available data, CPSC staff does not anticipate that using non-lead materials in wicks would result in increased costs to manufacturers or consumers since most companies already use non-lead materials. Finally, officials in

Australia and New Zealand have acted to eliminate lead-cored wicks in their countries.

Lead in metal cores: A number of commenters believe that no lead exposure from candles or any consumer product should be allowed. Since metals, such as zinc and tin, used as wick cores may contain lead, these commenters believe that all metal cored-wicks should be banned.

Response: The staff agrees that lead may be a contaminant of metals used as wick cores. Although the staff believes that the lead content of wicks should be minimized as much as technologically feasible, the very small amounts of lead (*i.e.*, 0.06% or less) in metal wicks are unlikely to contribute hazardous levels of lead in children. Thus, these products would not meet the definition of a hazardous substance under the FHSA, and could not be subject to a ban under the Act.

ASTM proposal: Several commenters, including the petitioner Public Citizen, observed that while it would be most desirable for candle wicks to contain no lead at all, it would be acceptable to allow the use of high grade metals with very small levels of lead contamination.

Response: A task group for candle wicks under the ASTM F15.45 Candle Products subcommittee is in the process of developing a standard for lead content of metal-cored wicks. The staff is aware that the group has not finalized their proposal and is currently considering a maximum lead level of 0.02%. Although the staff believes that the lead content of wicks should be minimized as much as technologically feasible, the very small amounts of lead in metal wicks are unlikely to contribute hazardous levels of lead in children.

Other metal cores: Two commenters believe that consumers should be warned about the potential dangers from exposure to metals such as zinc or tin.

Response: CPSC staff has measured zinc releases from burning zinc-cored wick candles, but the levels were lower than the levels observed to cause illness in humans or experimental animals exposed to zinc fume or dust. Tin emissions from candles have not been determined, but the long-term exposures to high levels of dust experienced by workers are not expected for consumers who burn candles. Further, the lungs of workers exposed to relatively large amounts of tin compounds did not show tissue reactions, and the workers experienced no impairment of pulmonary function or systemic disease. Therefore, the staff has no basis to believe that zinc or tin emissions from burning candles with metal-cored wicks represent a hazardous exposure to these metals.

Label candles: Four commenters believe that if lead-cored wicks or candles containing lead cores cannot be banned immediately, consumers should be warned that the product contains lead.

Response: Staff analysis showed that since lead is emitted from a candle when the wick is lit, no label or subsequent action by the consumer would prevent the release of lead into the air when the candle is used as intended. Further, it is not realistic to expect a candle to be used for decorative purposes only and not be lit.

The staff believes that lead-cored wicks and candles containing lead-cored wicks should be banned and that labeling is not an acceptable strategy for protecting vulnerable populations from lead poisoning that may be induced by burning candles with lead-cored wicks.

Options

Grant the Petition and Publish an ANPR

If the Commission concludes that it is appropriate, the Commission could grant the petition and begin a proceeding to ban lead-cored wicks containing more than 0.06% lead by weight in the metal by publishing an ANPR in the Federal Register.

Deny the Petition and Not Publish an ANPR

If the Commission concludes that information is not available or likely to be developed to support the findings required by section 2(q)(1)(B) and 3(i)2 of the FHSA to ban lead-cored wicks, the Commission could vote to deny the petition.

Conclusions and Recommendation

Staff review of the Petition and available data results in the following conclusions: 1) lead exposure from burning candles with lead-cored wicks can present a risk of lead poisoning; 2) it is not possible to predict lead exposure from the lead content of the wick; 3) substitutes for lead-cored wicks are available and currently in use; 4) candle wicks with metal cores containing 0.06% lead or less are unlikely to release hazardous amounts of lead; and 5) past experience indicates that voluntary industry agreements are unlikely to be effective over time.

Therefore, the staff recommends that the Commission grant the petition and begin a proceeding to ban metal-cored wicks containing more than 0.06% lead by weight in the metal by publishing an ANPR in the Federal Register.

References

CDC (1991) Preventing Lead Poisoning in Young Children: A Statement by the Centers for Disease Control. Atlanta, Georgia: U.S. Department of Health and Human Services, Public Health Service.

CDC (1997) Update: Blood Levels-United States, 1991-1994. Morbidity and Mortality Weekly Report 46(7): 141-146. Erratum: 46(26): 607.

CPSC (1996) Report on Lead in Vinyl Miniblinds. 19 September 1996.

CPSC (1998) Federal Register 63: 70648. Codification of Guidance Policy on Lead in Consumer Products (16 CFR § 1500.230). 22 December 1998.

Shannon MW and Graef JW (1992) Lead Intoxication in Infancy. *Pediatrics 89(1)*: 87-90.

TAB A

1310

Public Citizen

Buyers Up • Congress Watch • Critical Mass • Global Trade Watch • Health Research Group • Litigation Group
Joan Claybrook, President

CPSC/OFFICE OF THE SECRETARY
2000 FEB 25 A 11

February 24, 2000

Ann Brown, Chairperson
US Consumer Product Safety Commission
Washington, DC 20207-0001

Dear Chairperson Brown:

We are petitioning the Consumer Product Safety Commission to immediately ban and recall all candles with lead-containing wicks, candles in metal containers that contain lead, and wicks sold for candle-making that contain lead as an imminent hazard to the public health on the grounds that continued sale of these items violates provisions of the Federal Hazardous Substances Act and the Consumer Product Safety Act. Additionally, we urge the Consumer Product Safety Commission to warn consumers of the potential dangers from exposure to ambient air metals emitted from candles containing metallic cores such as zinc or tin but do not contain lead.

In 1973, Public Citizen's Health Research Group petitioned the Consumer Product Safety Commission to remove candles with lead-containing wicks from the market.[1] However, in 1974, in lieu of a complete ban, the candle industry and CPSC arrived at a voluntary agreement to immediately stop making candles with lead-containing wicks. To determine whether this voluntary agreement has been effective, especially because of reports that these candles were once again being sold, we conducted a survey this month of 285 types of candles in 12 stores in the Baltimore-Washington D.C. area. We found that 3% (9/285) of all types of candles on store shelves had wicks containing significant quantities of lead, ranging from approximately 24,000 ug to 118,000 ug (33-85 percent lead by weight). Each of these 9 candles, when burned for 3 hours daily in a 15 ft. by 15 ft. by 8 ft. room, would result in average 24-hour air lead levels ranging from 14-49 ug/m^3, 9-33 times the EPA Air Quality Standard for lead. Other studies done in the past two years found that candles purchased in Michigan and Florida also had lead-containing wicks. History has shown that the 1974 voluntary agreement has failed. Furthermore,

[1]Public Citizen's Health Research Group, Letter to Richard D Simpson, Chairman, Consumer Product Safety Commission, December 6, 1973.

Ralph Nader, Founder
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labeling of lead-containing candles will not suffice to protect the people most susceptible to lead toxicity: fetuses, infants and young children. Even if all U.S. candle manufacturers, who currently sell $2.3 billion dollars worth of candles annually,[2] stopped using lead now, millions of candles with lead-containing wicks would remain on the shelves and imports would probably continue or might even increase. These reasons necessitate a complete ban and recall of these hazardous products.

At least one country has recently tackled this problem definitively. In September 1999, Australian Minister of Financial Services and Regulation Joe Hockey ordered the ban of all candles with wicks containing lead. He recognized that "Public health experts have confirmed that lead emissions from any source pose an unacceptable public health risk and can result in increased blood lead levels in unborn babies, babies and young children....Public health experts have confirmed that the candles pose a risk to public health if burned in a confined space."[3]

In this petition, Public Citizen's Health Research Group documents the following:

1. ***Candles with wicks containing lead are currently on store shelves and millions are sold annually.***
2. ***Burning candles with wicks containing lead causes high lead exposure both through air and surface contact.***
3. ***The air and surface lead levels produced by candles with lead-containing wicks are sufficient to significantly raise blood lead levels.***
4. ***The increased blood lead levels from burning these candles can cause permanent deficits in development, behavior, and intelligence.***
5. ***Alternatives to lead-containing wicks exist.***
6. ***Labeling will not adequately protect candle-users.***
7. ***The Consumer Product Safety Act and the Hazardous Substances Act require the Consumer Product Safety Commission to ban and recall these products.***

BACKGROUND ON LEAD

Effects of lead exposure: Lead has been known to adversely affect health since antiquity. Hippocrates (370 BC) noted lead to have caused a severe attack of colic.[4] The ruling class of Romans was heavily exposed to lead through wares and lead in syrups used to sweeten wine. Consequently, gradual lead poisoning may explain the eccentric behavior and insanity of many

[2] Candle industry facts. The National Candle Association home page. Internet web site (http://www.candles.org/facts.htm). National Candle Association; 1030 15th Street, Suite 870, Washington, DC 20005.

[3] The Honorable Joe Hockey, The Minister for Financial Services & Regulation, Australia. Hockey Bans Lead Candle Wicks. Press release, 9/1/99. Available at http://www.minfsr.treasury.gov.au/

[4] Hunter D. The Diseases of Occupations. The English Universities Press LTD, 4th ed. p. 235, 1969.

of the Roman emperors that ultimately led to the fall of the Roman Empire.[5] Similar exposures may explain eccentric behaviors of the British ruling class in the 18th century.[6] More recently, chronic lead exposure has been implicated in high blood pressure, digestive problems, nerve disorders, memory and concentration problems, muscle and joint pain,[7] encephalopathy (pathologic changes of the brain) and death.[8] Furthermore, decreased intelligence,[9] minor antisocial behavior,[10] increased high school dropout rates,[11] and impaired development,[12]

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[5] Emsley, J. When the Empire struck lead. The gradual poisoning of the ruling classes in ancient Rome with lead may have caused the downfall of their empire. Did the British Empire suffer the same fate? New Scientist, 25 December 1986- 1 January 1987, pp. 64-67.

[6] Ibid.

[7] Consumer Product Safety Commission, Protect your family from lead in your home. CPSC Document #426. EPA747-K-94-001, May 1995.

[8] Klaassen CD. Heavy metals and heavy-metal antagonists, in Goodman and Gilman's: The pharmacological basis of therapeutics. 9th ed. Chapter 66, p.1650-1652, Mc Graw-Hill, New York. 1996.

[9] Baghurst PA, McMichael AJ, Wigg NR, et al. Environmental exposure to lead and children's intelligence at the age of seven years. The Port Pirie Cohort Study. The New England Journal of Medicine 327: 1279-1284, 1992.

Dietrich KN, Berger OG, Succop PA, et al. The developmental consequences of low to moderate prenatal and postnatal lead exposure: Intellectual attainment in the Cincinnati lead study cohort following school entry. Neurotoxicology and Teratology 15:37-44, 1993.

Fulton M, Raab G, Thomson G, et al. Influence of blood lead on the ability and attainment of children in Edinburgh. Lancet 1:1221-1226, 1987.

Needleman HL, Gatsonis CA. Low-level lead exposure and the IQ of children. A meta-analysis of modern studies. Journal of the American Medical Association 263: 673-678, 1990.

Needleman HL, Gunnoe C, Leviton A, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. The New England Journal of Medicine 300:689-695, 1979.

Needleman HL, Geiger SK, Frank R. Lead and IQ Scores: A reanalysis. Science 227, 701-704, 1985.

Schwartz J. Low-level lead exposure and children's IQ: A meta-analysis and search for a threshold. Environmental Research 65:42-55, 1994.

Tong S, Baghurst PA, Sawyer MG, et al. Declining blood lead levels and changes in cognitive function during childhood. The Port Pirie Cohort Study. Journal of the American Medical Association 280: 1915-1919, 1998.

Tong S, Baghurst P, McMichael A, et al. Lifetime exposure to environmental lead and children's intelligence at 11-13 years: the Port Pirie Cohort Study. British Medical Journal 312:1569-1575, 1996.

[10] Needleman HL, Schell A, Bellinger D, et al. The long-term effects of exposure to low doses of lead in childhood: An 11-year follow-up report. The New England Journal of Medicine 322: 83-88, 1990.

[11] Ibid.

coordination,[13] learning[14] and reading[15] occur at lead levels previously considered acceptable.

Routes of exposure to lead: In general, environmental lead is either inhaled or ingested. Lead in candles can enter the blood by both routes. The route of entry plays a major role in determining the amount of lead that enters the bloodstream.

The candlewick lead content and the percent lead vaporized determine the total lead emitted. In the past, industry argued that lead in wicks does not vaporize. In 1974, Corning claimed that "at candle temperature, lead vaporizes at the same rate as ice does at 13 degrees below zero."[16] However, two studies, one by EPA in 1973 and another recent study, have shown that 20-35% of the lead in pure lead candle wicks is vaporized.[17, 18] The total lead emitted and the size and ventilation of the room determine the ambient air lead concentration. The respiratory rates and volume, time of exposure and ambient air lead concentration determine the amount of lead that reaches the lung lining (the epithelium) and about 90% of that is absorbed into the blood.[19]

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[12] Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

Mendelsohn AL, Dreyer BP, Fierman AH, et al. Low-level lead exposure and cognitive development in early childhood. Journal of Developmental and Behavioral Pediatrics. 20: 425-431, 1999.

McMichael AJ, Baghurst PA, Wigg NR, et al. The Port Pirie Cohort Study: Environmental exposure to lead and children's abilities at the age of four years. The New England Journal of Medicine 319: 468-475, 1988.

Wigg NR, Vimpani GV, McMichael AJ, et al. Port Pirie Cohort Study: Childhood blood lead and neuropsychological development at age two years. Journal of Epidemiology and Community Health 42: 213-219, 1988.

[13] Dietrich KN, Berger OG, Succop PA. Lead exposure and the motor developmental status of urban six-year-old children in the Cincinnati Prospective Study. Pediatrics 91: 301-307, 1993.

[14] Needleman HL, Schell A, Bellinger D, et al. The long-term effects of exposure to low doses of lead in childhood: An 11-year follow-up report. The New England Journal of Medicine 322: 83-88, 1990.

[15] Needleman HL, Schell A, Bellinger D, et al. The long-term effects of exposure to low doses of lead in childhood: An 11-year follow-up report. The New England Journal of Medicine 322: 83-88, 1990.

[16] Press Release by Corning, January 8, 1974.

[17] Bridbord K, Medical Officer. Memo to Stanley Greenfield, Assistant Administrator for Research and Development, and Vaun A. Newill, Special Assistant to the Administrator: Hazards of burning candles with lead. US EPA, Research Triangle Park, December 14, 1973.

[18] Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment 243-244: 53-65, 1999.

[19] Goyer RA, Toxic effects of metals. In Casarett and Doull's, Toxicology, The Basic Science of Poisons. 4th ed. Pergammon Press, 1991.

Particulate airborne lead from burning candles settles as house dust. Children inhale and ingest dust stirred during crawl and play. They track it on their hands or clothes, pick up dust-laden objects and put them in their mouths. As lead tastes sweet, they may lick the dust from their hands. Furthermore, most vacuum cleaners stir up huge dust loads.[20] Finally, ventilation duct turbulence causes fine particulate matter typical of candle emissions, to become charged and attracted to plastic surfaces. Krause notes that this matter particularly covers kitchen surfaces, such as plastic utensils, ice cube trays and refrigerator/freezer surfaces.[21]

Additional lead exposure can occur from dust settling in food after being warmed by lead-containing warming candles and, less likely, from children ingesting the wick.

Current Regulations: There are four relevant government standards referred to in this petition:

1. Blood lead levels: The Centers for Disease Control and Prevention (CDC) currently recommend keeping children's blood lead levels below 10 ug/dl (100 ml). The CDC has stated that no threshold is known below which lead is safe and that harmful effects may occur at levels below 10 ug/dl, but that the body of information accumulated thus far is insufficient to prove this.[22]
2. Average total daily dose of lead: The Consumer Product Safety Commission (CPSC) recommends limiting chronic lead ingestion in children less than 6 years old to less than 15 ug/day to prevent blood lead levels from exceeding 10 ug/dl.[23]
3. Ambient air lead level: The Environmental Protection Agency (EPA) ambient air guideline for lead is 1.5 ug/m^3.[24] This level corresponds to an average total daily dose of inhaled lead of 30 ug for an average child less than 6 years old, [25] double what the CPSC reports as a safe level.
4. Surface lead levels: The U.S. Housing and Urban Development (HUD) standard for surface lead dust levels of carpeted or bare floors, window sills and window wells are 100 ug/ft^2 (1075 ug/m^2), 500 ug/ft^2 (5400 ug/m^2) and 800 ug/ft^2 (8610 ug/m^2).[26] As several studies have

[20] Lioy PH, Wainman T, Zhang J, et al. Typical household vacuum cleaners: the collection efficiency and emissions characteristics for fine particles. Journal of the Air and Waste Manage Association. 49:200-206, 1999.

[21] Krause D., personal communication, 10 Feb 99. Mr. Krause has written a Master's thesis on candle emissions.

[22] U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control. Preventing. lead poisoning in young children. pp. 7-8, October 1, 1991.

[23] Consumer Product Safety Commission. CPSC Staff report on lead and cadmium in children's polyvinylchloride (PVC) products. Page 5. 21 November 1997.

[24] Code of Federal Regulations. Title 40--Protection of Environment, Chapter 1--Environmental Protection Agency, Part 50, Sec 50.12 National primary and secondary ambient air quality standards for lead.

[25] Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

[26] http://www.hud.gov:80/lea/leach1.pdf: Chapter 1: Introduction. Legislative Basis and Relationship to Federal Programs and Regulations. In The Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in

correlated high blood lead levels with these levels, the EPA is proposing lowering them to 50 ug/ft^2 (540 ug/m^2) and 250 ug/ft^2 (2700 ug/m^2) for bare floors and windowsills, respectively.[27] Even the latter may not be sufficiently low. One study found that 20% of children living with a lead dust level of 430 ug/m^2 had blood lead levels above 10 ug/dl and that lower lead dust levels predicted lower blood lead levels.[28] Another study found that decreasing the lead dust level from 240 ug/m^2 (less than half the EPA recommendation) to 160 ug/m^2 reduced average blood lead levels from 12.4 to 10.3 ug/dl,[29] still above the CDC levels.

1. Candles with wicks containing lead are currently on store shelves and millions are sold annually.

In February 2000, Public Citizen's Health Research Group conducted a study of the lead content of candles in the Baltimore-Washington area. We selected 11 chain stores and one dollar store to represent the places where candles are most commonly purchased. These were: CVS Pharmacy, The Dollar Shop, Hallmark, Walmart, Kohl's, Bath and Body Works, The Body Shop, Hecht's, Target, BJ's Wholesale, Jo-Anne Fabrics, and Bed, Bath and Beyond. We excluded candle stores because we believe that candles are more commonly purchased from non-specialty stores. (In fact, candle stores may be more likely to sell candles containing lead-wicks because of the properties lead confers on candles.) In each store, we selected one candle of each brand and type. Examples of candle types are pillars, containers, votives, tea lights, and novelty candles. Different colors, sizes and shapes of the same candle were considered a single type of candle. For each candle, we recorded the store name and location, manufacturer, candle type, and the presence or absence of a metallic wick. We then purchased one candle of each type containing a visible metallic wick. Each metallic wick was extracted from the wax, measured for length and mass, and tested for lead using Inductively Coupled Plasma Spectroscopy (ICP) by a laboratory accredited by the American Industrial Hygiene Association Environmental Lead Laboratory Accreditation Program.[30] The technique involves dissolving the samples in a known amount of nitric acid, performing spectroscopy on the solution, and comparing the intensity of the lead lines with samples of known quantities of lead.[31]

Thirty percent (86 of 285) of types of candles contained metallic wicks. We found that 10%

Housing, 1995.

[27] US Environmental Protection Agency. EPA Fact Sheet. Proposed rule on identification of lead-based paint hazards. #747-F-98-001, June 1998.

[28] Lanphear BP, Weitzman M, Winter NL et al. Lead-contaminated house dust and urban children's blood lead levels. American Journal of Public Health 86:1416-21, 1996.

[29] Rhoads GG, Ettinger AS, Weisel CP, et al. The effect of dust lead control on blood lead in toddlers: a randomized trial. Pediatrics 103: 551-555, 1999.

[30] Specimens were analyzed at RJ LeeGroup, Inc., Monroeville, PA.

[31] Elements by ICP, Method 7300, Issue 2. In NIOSH Manual of Analytical Methods (NMAM), 4th ed., August 14, 1994.

(9/86) of candles with metallic wicks contained lead for an overall prevalence of candles containing lead of 3% (9/285). Table 1 shows that the total lead content of the nine candles containing lead wicks ranged from approximately 24,000 ug to 118,000 ug, (accounting for 33% to 85% of the weight of the metal in the candlewick). Assuming that only 20% of the lead in the candlewick is emitted into the air, this corresponded to 4700 ug to 24,000 ug of airborne lead from a single wick. As the percentage of lead from a candlewick emitted into the air ranges from 20-35%,[32] the actual amount emitted may be considerably higher. A typical room of 15 ft. x 15 ft. x 8 ft. has a total volume of 51 m^3. If these candles burned at a rate of 2 cm/hour for three hours daily (and were extinguished after 3 hours) in such a room with 25% per hour ventilation rates, they would yield ambient air lead concentrations ranging from 14 to 49 ug/m^3, which is 9-33 times the EPA Ambient Air Quality Standard. If we assume instead that we burned the candle emitting the least lead under the same conditions, except that the burn rate is only 0.5 cm/hour (1/4 the original assumption), and that the room has a ventilation rate of 50% (twice the original assumption), we still get ambient air levels of 1.2 ug/m^3, approximating the EPA Ambient Air Lead Standard.

Furthermore, lead exposure may occur due to dust and dust may accumulate even with vacuuming. Using van Alphen's assumption that between 5-10% of dust deposits on the floor,[33] and the results of Roberts et al. who found that only 10% of lead dust was trapped by vacuuming,[34] even with weekly vacuuming, dust lead levels may reach 540 ug/m^2, the proposed limit set by the EPA.[35]

We found that 2 lead-containing candles were pillars, 6 were containers, and 1 was a votive. None of the tapers, novelty or tea lights tested contained lead.

We are aware of one previous case study and two previous lead wick prevalence studies. In 1999 in Australia, van Alphen reported that 7 candles imported from China had almost pure lead-core wicks (95-99% lead).[36] That same year Nriagu and Kim purchased 14 candles with wicks

[32]Bridbord K, Medical Officer. Memo to Stanley Greenfield, Assistant Administrator for Research and Development, and Vaun A. Newill, Special Assistant to the Administrator: Hazards of burning candles with lead. US EPA, Research Triangle Park, December 14, 1973.

Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

[33] van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb metal wick cores. Science of the Total Environment 243-244: 53-65, 1999.

[34] Roberts JW, Glass GL, and Spittler TM. Measurement of deep dust and lead in old carpets. In: Measurement of toxic and related pollutants, Air and Waste Management Assoc., Pittsburgh, pp.186-191, 1995.

[35] US Environmental Protection Agency. EPA Fact Sheet. Proposed rule on identification of lead-based paint hazards. #747-F-98-001, June 1998.

[36] van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb metal wick cores. Science of the Total Environment 243-244: 53-65, 1999.

containing metallic cores in stores in Ann Arbor, Michigan. They reported that all 14 candles with metallic wicks emitted lead during burning.[37] In August 1999, Krause purchased candles with metallic wicks from every store selling candles in a mall in Tampa, Florida. He noted that each store was part of a different nationwide chain. He found that the 24% (5 of 21) of metallic candlewicks that contained lead did so at levels of 1.25, 9.5, 14, 42, and 46 weight % lead.[38] In an earlier study, he purchased 91 candles over a two-year period in both Florida and California. None of the 21 candles with metallic wicks and one with a metallic containers from California emitted lead. However, 4 of 6 candles with metallic wicks purchased in Florida emitted lead. Combining these results with previous work, he found that approximately 9 of 27 candles with metallic wicks contained lead. All candles with wicks containing lead were purchased in Florida.[39]

Atkins and Pierce, the major U.S. manufacturer of all types of wicks, admitted that because some candle makers kept using such wicks "since there wasn't an actual ban", they resumed the practice of making and selling wicks containing lead "in the late 70s or early 80s."[40] The company claims to have stopped the practice last year;[41] however, our study and others demonstrate that candles with lead-containing wicks are prevalent in many states.[42] Moreover, lead-containing wicks for candle making are currently sold directly over the Internet.[43]

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[37]Nriagu JO, Kim MJ, Emissions of Lead and Zinc from Candles with Metal-Core Wicks. Science of the Total Environment, in press, 2000.

[38] Krause D. Personal communication, 26 January 2000.

[39]Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Krause D. Personal communication, 26 January 2000.

[40]Notes from the Meeting with CPSC and National Candle Association on 12/15/99.

[41]Ibid.

[42] Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Krause D. Personal communication, 26 January 2000.

Nriagu JO, Kim MJ, Emissions of Lead and Zinc from Candles with Metal-Core Wicks. Science of the Total Environment, in press, 2000.

van Alphen M, Emission testing and inhalational exposure-based risk assessment for candles having Pb metal wick cores, Science of the Total Environment 243-244: 53-65, 1999.

[43] CANDLECHEM COMPANY, Inc. http://www.alcasoft.com/candlechem/

Candle sales exceeded $2.3 billion last year.[44] We estimate that over 300 million candles were sold in the U.S. in 1999 based on our finding that the average candle costs $7.35. If 3% of the candles sold contain lead, approximately 12 million candles sold in the United States each year contain lead, assuming our sample is representative of all candles sold.

2. Burning candles with wicks containing lead causes high lead exposure both through air and surface contact.

A. Ambient Air Exposure: The work of four groups of researchers discussed in this section pertains to the high ambient lead levels that result from burning lead-wick containing candles. The last study pertains to the resulting high surface lead concentration.

In 1973, immediately following our petition to ban lead wicked candles,[45] EPA researchers determined that burning candles with lead-containing wicks exceeded the current EPA air quality standard by over 10 times. In this experiment, they burned 4 candles with lead-core wicks on a dining room table in a 10 square foot dining room and monitored air lead for 13 hours. Over this period, the air lead concentrations averaged 16 ug/m^3—over 10 times the current EPA air lead guideline. Their experimental apparatus was unable to detect lead in particles below 0.1 um and therefore the average lead concentrations may have been higher. The EPA researchers concluded, "Based upon these observations it would not be unreasonable to expect average indoor air lead levels in the range of 10-20 ug/m^3 [6-12 times above EPA's air quality standard] as a result of regularly burning candles with lead wire core wicks in the home. Further...the remaining lead residue from these candles could also be a hazard by inadvertent contamination of food or by being available for children to ingest."[46]

From October 1997 until August 1999, Krause purchased 85 candles of which 21 had metallic wicks and 1 had a container in California and 6 from Florida for a total of 27 candles with metallic wicks and one with a metallic container. He burned the candles in a chamber and characterized their emissions. For those candles containing metallic wicks, he estimated exposure using his own model and using an EPA exposure model (US EPA RISK V1.0 Indoor Air Quality Exposure Model), which produced similar results. Finally, he calculated lead exposure for children. None of the 21 candles with metallic wicks and the one metallic container candle from California emitted lead. However, 4 of 6 candles

[44]Candle industry facts. The National Candle Association home page. Internet web site (http://www.candles.org/facts.htm). National Candle Association; 1030 15th Street, Suite 870, Washington, DC 20005.

[45]Public Citizen's Health Research Group, Letter to Richard D Simpson, Chairman, Consumer Product Safety Commission, December 6, 1973.

[46]Bridbord K, Medical Officer. Memo to Stanley Greenfield, Assistant Administrator for Research and Development, and Vaun A. Newill, Special Assistant to the Administrator: Hazards of burning candles with lead. US EPA, Research Triangle Park, December 14, 1973.

with metallic wicks purchased in Florida emitted lead. When burning one candle for 4 hours daily, he estimated that two of these candles would result in children under 6 inhaling an average daily dose of lead of 40 and 95 ug, respectively.[47] Both exceeded the maximum acceptable level recommended by the CPSC (15 ug) by several times.[48] A third candle resulted in an average daily dose of 13 ug.[49]

In 1999 in Michigan, Nriagu and Kim burned 15 types of candles (14 purchased in Michigan) with metallic wicks over 2 to 7 hours and measured the lead emitted into an experimental chamber. Lead emitted after burning one candle in a typical room for 2 hours extrapolated to air lead concentrations of 0.02 to 13.1 ug/m^3 with five candles exceeding the U.S. EPA ambient air lead guideline of 1.5 ug/m^3.[50] However, 24-hour average air lead concentrations were not calculated.

In 1999, Van Alphen burned seven candles with high lead content in an experimental chamber to determine the amount of lead emitted. From this, he estimated average 24-hour air lead levels. He reported that burning one candle with high lead content for 3 hours could achieve a 24-hour average lead concentration of 10 ug/m^3,[51] almost seven times the EPA ambient air guideline of 1.5 ug/m^3.

Therefore, three studies have shown that episodic burning of candles with a lead-core wick can expose people to average ambient lead concentrations above the limit set by EPA and one study showed that inhaled lead exceeded the limits set by the CPSC for children.[52]

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[47]Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Personal communication with David Krause, 26 January 2000.

[48] Consumer Product Safety Commission. CPSC Staff report on lead and cadmium in children's polyvinylchloride (PVC) products. Page 2. 21 November 1997.

[49]Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

[50]Nriagu JO, Kim MJ, Emissions of Lead and Zinc from Candles with Metal-Core Wicks. Science of the Total Environment, in press, 2000.

[51]Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

[52]Bridbord K, Medical Officer. Memo to Stanley Greenfield, Assistant Administrator for Research and Development, and Vaun A. Newill, Special Assistant to the Administrator: Hazards of burning candles with lead. US EPA, Research Triangle Park, December 14, 1973.

Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal

Thirty-five percent of candles in the Michigan study exceeded the EPA standards; however, Nriagu and Kim did not calculate 24-hour average air lead concentrations.[53]

B. Surface Lead Exposure: Particulate vaporized lead eventually settles in the form of house dust and soot. Unlike ambient air lead, which requires a daily or weekly source to keep levels high, surface lead may accumulate from infrequently burning candles even with regular vacuuming, leading to ongoing exposure.[54] Van Alphen reports that "A single 38 cm long candle [with high lead content] can emit 104,000 ug Pb [lead] into the air. The deposition of as little as 5 to 10 % of that onto the floor of a 5x5 m room would result in a floor Pb loading of approximately 150 to 300 ug/m^2. Such a floor loading would readily be associated with elevations in child blood lead."[55] Burning only two to four of these candles will result in surface lead concentrations exceeding even the EPA proposed limits of 540 ug/m^2 for floor surface lead concentration.[56] Recall that these limits are not sufficient to protect children from high blood lead levels.[57]

3. The air and surface lead levels produced by candles with lead-containing wicks are sufficient to significantly raise blood lead levels.

A. Ambient Air lead: Exposing adult males 23 hours per day over 18 weeks to air lead levels of either 3.2 ug/m^3 or 10 ug/m^3 increased their blood lead concentrations by 12 ug/dl and 22 ug/dl, respectively.[58] The WHO reports that each 1 ug/m^3 ambient concentration of lead contributes 1.9 ug/dl of blood lead in children (approximately linearly in the lower part of the range), but that inhalation is relatively less important in children compared to ingestion. Thus, correcting for ingestion, the WHO estimates that each 1 ug/m^3 increase

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wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

[53] Nriagu JO, Kim MJ, Emissions of Lead and Zinc from Candles with Metal-Core Wicks. Science of the Total Environment, in press, 2000.

[54] Roberts JW, Glass GL, and Spittler TM. Measurement of deep dust and lead in old carpets. In: Measurement of toxic and related pollutants, Air and Waste Management Assoc., Pittsburgh, pp. 186-191, 1995.

[55] Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

[56] US Environmental Protection Agency. EPA Fact Sheet. Proposed rule on identification of lead-based paint hazards.

[57] Lanphear BP, Weitzman M, Winter NL et al. Lead-contaminated house dust and urban children's blood lead levels. American Journal of Public Health 86:1416-21, 1996.

Rhoads GG, Ettinger AS, Weisel CP, et al. the effect of dust lead control on blood lead in toddlers: a randomized trial. Pediatrics 103: 551-555, 1999.

[58] Griffin TB, Coulston F, Wills H, et al. Clinical studies on men continuously exposed to airborne particulate lead. Environmental Quality and Safety Supplement 2: 221-40, 1975.

in ambient air lead level contributes 5 ug/dl to the blood lead level.[59] Brunekreef critically reviewed 19 studies and found that in children the relationship between blood lead and ambient air lead is logarithmic. In young children at blood levels less than 25 ug/dl, he found that 1 ug/m^3 increases in air lead concentrations contributed 3-5 ug/dl increases in blood lead level. At lower air levels, increases in exposure produce even greater increases in blood lead levels. Brunekreef states that up to "a few ug/m^3," each 1 ug/m^3 can increase blood lead levels by over 5 ug/dl.[60]

To our knowledge, only Krause and Van Alphen directly relate ambient air lead levels emitted from candles to children's blood lead levels. Krause determined that burning the candle with the highest lead content in his study for four hours daily may raise a 2-3 year-old child's blood lead level by 4.2 ug/dl to 13.4 ug/dl. He determined this using the Integrated Exposure Uptake Biokinetic Lead Model, a model that calculates serum lead levels by incorporating parameters such as ventilation rates, baseline indoor air lead concentrations, time indoors, and soil and house dust concentrations.[61]

Van Alphen burned candles with wicks containing very high lead content to determine the amount of lead emitted. From this, he estimated average 24-hour air lead levels and corresponding blood lead levels from burning one candle for three hours under varying conditions including room sizes, ventilation rates, and rates of increase of blood lead level for every unit increase in air lead level. Using a wide range of assumptions, he estimated that burning one candle three hours per week will raise a child's blood lead level by 3-11 ug/dl above the unexposed baseline and that burning one candle daily could raise it by 12-40 ug/dl. Van Alphen concludes, "There is the potential for entire families to have high Pb [lead] exposures because of such a Pb source. Where multiple Pb metal wick core candles are burned on a regular basis, for periods of >3 to 6 hours, in poorly ventilated settings, extreme levels of Pb exposure are possible. Clinical child Pb poisoning and death could be predicted."[62]

B. Surface lead. Rhoads et al. compared household lead dust levels to blood lead levels in children randomized to groups where members of the intervention group were instructed to regularly clean their household to reduce lead exposure. Prior to the intervention, the

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[59]World Health Organization. Guidelines for Air Quality, 1999. Chapter 3: Health-based Guidelines, 41.

[60]Brunekreef B. The Relationship between Air Lead and Blood Lead in Children: A Critical Review. Science of the Total Environment, 38: 79-123, 1984.

[61]Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Krause D. Personal communication, 26 January 2000.

[62]Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

intervention group had a mean floor dust lead level of 237 ug/m^2 and a mean blood lead level of 12.4 ug/dl. After the intervention, their floor dust lead levels decreased to 163 ug/m^2, and their blood lead decreased to 10.3 ug/dl. The control group had floor dust lead levels of 275 at baseline and 207 ug/m^2 at follow up and the blood lead levels remained constant at 11.6 ug/dl.[63]

As Van Alphen estimated that burning one 38 cm long candle with a pure lead wick in a 5x5 m room will result in 150 to 300 ug/m^2 surface lead dust levels on floors, infrequent burning of these candles could easily accumulate lead sufficiently to cause elevated blood lead levels.[64]

4. The increased blood lead levels from burning these candles can cause permanent deficits in development, behavior, and intelligence.

Most recent studies have shown that blood lead levels above 10 ug/dl adversely affect children. Unborn and young children are particularly susceptible to even low blood lead levels. Placental exposure may result in miscarriage or early neonatal death,[65] premature births[66] and decreased mental ability.[67] For example, table 2 shows two longitudinal studies. After adjusting for confounding, Bellinger et al. showed that infants previously exposed to umbilical cord blood lead levels of 10 ug/dl or greater performed 5.8 points lower at six months and 7.3 points lower at

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[63] Rhoads GG, Ettinger AS, Weisel CP, et al. the effect of dust lead control on blood lead in toddlers: a randomized trial. Pediatrics 103: 551-555, 1999.

[64] Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

[65] Wibberley DG, Khera AK, Edwards JH, et al. Lead levels in human placentae from normal and malformed births. Journal of Medical Genetics 14: 339-345, 1977.

[66] Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

[67] Bellinger DC, Needleman HL, Leviton A, et al. Early sensory-motor development and prenatal exposure to lead. Neurobehavioral Toxicology and Teratology 6: 387-402, 1984.

Bellinger DC, Leviton A, Waternaux C, et al. Methodological issues in modeling the relationship between low-level lead exposure and infant development: Examples from the Boston lead study. Environmental Research 38: 119-129, 1985.

Bellinger D, Leviton A, Needleman HL, et al. Low-level lead exposure and infant development in the first year. Neurobehavioral Toxicology and Teratology 8: 151-161, 1986.

Bellinger D, Leviton A, Waternaux C, et al. Longitudinal analyses of prenatal and postnatal lead exposure and early cognitive development. The New England Journal of Medicine 316: 1037-1043, 1987.

Dietrich KN, Krafft KM, Bornschein RL, et al. Low-level fetal lead exposure effect on neurobehavioral development in early infancy. Pediatrics 80: 721-730, 1987.

twelve months on the Mental Development Index (MDI) of the Bayley Scales of Infant Development than those with blood levels less than 3 ug/dl.[68] The MDI is a commonly used test based on the IQ scale for assessing early cognitive development.[69] In a second study, mean levels were 8.0 and 6.3 for maternal blood and umbilical cord blood, respectively. No blood levels were above 30 ug/dl. After adjusting for confounding, for every ug/dl increase in blood lead, there was a 0.34 point decrease in Bayley MDI score.[70] In summary, both studies found that at each level, as the umbilical cord blood or maternal blood lead level increased over a range starting well below 10 ug/dl, performance on a developmental test declined.

Lead has also been implicated in prematurity. One study found that those with maternal blood lead levels of greater than 14 ug/dl had 4.4 times the risk of prematurity of those with blood lead levels less than 8 ug/dl.[71]

There is evidence that damage caused by low-level lead exposure in children becomes evident at an early age and persists into adulthood. Tables 3 and 4 show that, after adjusting for socioeconomic factors and other potential confounders, this damage includes deficits in development, intelligence, learning, and behavior in early childhood-preschool children,[72] school-aged children,[73] and young adults.[74] Table 3 shows that incremental increases in blood

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[68]Bellinger DC, Leviton A, Needleman HL, et al. Low-level lead exposure and infant development in the first year. Neurobehavioral Toxicology and Teratology 8: 151-161, 1986.

[69] Bayley N. Bayley Scales of Infant Development. New York, The Psychological Corporation, 1969.

[70]Dietrich KN, Krafft KM, Bornschein RL, et al. Low-level fetal lead exposure effect on neurobehavioral development in early infancy. Pediatrics 80: 721-730, 1987.

[71]Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

[72] Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

Mendelsohn AL, Dreyer BP, Fierman AH, et al. Low-level lead exposure and cognitive development in early childhood. Journal of Developmental and Behavioral Pediatrics. 20: 425-431, 1999.

McMichael AJ, Baghurst PA, Wigg NR, et al. The Port Pirie Cohort Study: Environmental exposure to lead and children's abilities at the age of four years. The New England Journal of Medicine 319: 468-477, 1988.

Wigg NR, Vimpani GV, McMichael AJ, et al. Port Pirie Cohort Study: Childhood blood lead and neuropsychological development at age two years. Journal of Epidemiology and Community Health 42: 213-219, 1988.

[73]Baghurst PA, McMichael AJ, Wigg NR, et al. Environmental exposure to lead and children's intelligence at the age of seven years. The Port Pirie Cohort Study. The New England Journal of Medicine 327: 1279-1284, 1992.

Burns JM, Baghurst PA, Sawyer MG, et al. Lifetime low-level exposure to environmental lead and children's emotional and behavioral development at ages 11-13 years. The Port Pirie Cohort Study. American Journal of Epidemiology 149: 740-749, 1999.

lead over a range from 0 to 67 ug/dl at six months of age predicted poorer development and cognitive function in preschoolers using the MDI. Most children in these studies had blood lead concentrations below 30 ug/dl.[75] For example, Mendelsohn et al. found that children with blood levels between 0 and 9.9 ug/dl had 6.2 points higher MDI scores than children with blood lead levels between 10 and 25 ug/dl.[76]

Dietrich KN, Berger OG, Succop PA, et al. The developmental consequences of low to moderate prenatal and postnatal lead exposure: Intellectual attainment in the Cincinnati lead study cohort following school entry. Neurotoxicology and Teratology 15: 37-44, 1993.

Fulton M, Raab G, Thomson G, et al. Influence of blood lead on the ability and attainment of children in Edinburgh. Lancet 1: 1221-1226, 1987.

Needleman HL, Gatsonis CA. Low-level lead exposure and the IQ of children. A meta-analysis of modern studies. Journal of the American Medical Association 263: 673-678, 1990.

Needleman HL, Gunnoe C, Leviton A, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. The New England Journal of Medicine 300: 689-695, 1979.

Needleman HL, Geiger SK, Frank R. Lead and IQ Scores: A reanalysis. Science 227, 701-704, 1985.

Schwartz J. Low-level lead exposure and children's IQ: A meta-analysis and search for a threshold. Environmental Research 65: 42-55, 1994.

Tong S, Baghurst PA, Sawyer MG, et al. Declining blood lead levels and changes in cognitive function during childhood. The Port Pirie Cohort Study. Journal of the American Medical Association 280: 1915-1919, 1998.

Tong S, Baghurst P, McMichael A, et al. Lifetime exposure to environmental lead and children's intelligence at 11-13 years: the Port Pirie Cohort Study. British Medical Journal 312: 1569-1575, 1996.

[74] Needleman HL, Schell A, Bellinger D, et al. The long-term effects of exposure to low doses of lead in childhood: An 11-year follow-up report. The New England Journal of Medicine 322: 83-88, 1990.

[75] Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

Mendelsohn AL, Dreyer BP, Fierman AH, et al. Low-level lead exposure and cognitive development in early childhood. Journal of Developmental and Behavioral Pediatrics. 20: 425-431, 1999.

McMichael AJ, Baghurst PA, Wigg NR, et al. The Port Pirie Cohort Study: Environmental exposure to lead and children's abilities at the age of four years. The New England Journal of Medicine 319: 468-475, 1988.

Wigg NR, Vimpani GV, McMichael AJ, et al. Port Pirie Cohort Study: Childhood blood lead and neuropsychological development at age two years. Journal of Epidemiology and Community Health 42: 213-219, 1988.

[76] Mendelsohn AL, Dreyer BP, Fierman AH, et al. Low-level lead exposure and cognitive development in early childhood. Journal of Developmental and Behavioral Pediatrics. 20: 425-431, 1999.

Table 4 shows that increases in blood lead levels in the range of 0 to 39 ug/dl at ages from birth to 6 years of age continue to predict impaired cognitive function into school age (6.5 to 13 year olds). Measures used to assess lead exposure include a single blood lead level, average lifetime blood lead levels, and dentin tooth lead levels. Lead in dentin shed from primary teeth (incisors), in bone, and average lifetime lead, consisting of 22 blood lead levels drawn over the first six years, are long-term measures of blood lead.[77] Higher blood lead levels, average lifetime blood lead levels or dentin lead levels predicted poorer IQ (or other intelligence) scores,[78] number

[77]Baghurst PA, McMichael AJ, Wigg NR, et al. Environmental exposure to lead and children's intelligence at the age of seven years. The Port Pirie Cohort Study. The New England Journal of Medicine 327: 1279-1284, 1992.

Burns JM, Baghurst PA, Sawyer MG, et al. Lifetime low-level exposure to environmental lead and children's emotional and behavioral development at ages 11-13 years. The Port Pirie Cohort Study. American Journal of Epidemiology 149: 740-749, 1999.

Dietrich KN, Berger OG, Succop PA, et al. The developmental consequences of low to moderate prenatal and postnatal lead exposure: Intellectual attainment in the Cincinnati lead study cohort following school entry. Neurotoxicology and Teratology 15: 37-44, 1993.

Fulton M, Raab G, Thomson G, et al. Influence of blood lead on the ability and attainment of children in Edinburgh. Lancet 1: 1221-1226, 1987.

Needleman HL, Riess JA, Tobin MJ, et al. Bone lead levels and delinquent behavior. Journal of the American Medical Association 275: 363-369, 1996.

Needleman HL, Gatsonis CA. Low-level lead exposure and the IQ of children. A meta-analysis of modern studies. Journal of the American Medical Association 263: 673-678, 1990.

Needleman HL, Gunnoe C, Leviton A, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. The New England Journal of Medicine 300: 689-695, 1979.

Needleman HL, Geiger SK, Frank R. Lead and IQ Scores: A reanalysis. Science 227, 701-704, 1985.

Schwartz J. Low-level lead exposure and children's IQ: A meta-analysis and search for a threshold. Environmental Research 65: 42-55, 1994.

Tong S, Baghurst PA, Sawyer MG, et al. Declining blood lead levels and changes in cognitive function during childhood. The Port Pirie Cohort Study. Journal of the American Medical Association 280: 1915-1919, 1998.

Tong S, Baghurst P, McMichael A, et al. Lifetime exposure to environmental lead and children's intelligence at 11-13 years: the Port Pirie Cohort Study. British Medical Journal 312: 1569-1575, 1996.

[78]Baghurst PA, McMichael AJ, Wigg NR, et al. Environmental exposure to lead and children's intelligence at the age of seven years. The Port Pirie Cohort Study. The New England Journal of Medicine 327: 1279-1284, 1992.

Dietrich KN, Berger OG, Succop PA, et al. The developmental consequences of low to moderate prenatal and postnatal lead exposure: Intellectual attainment in the Cincinnati lead study cohort following school entry. Neurotoxicology and Teratology 15: 37-44, 1993.

Fulton M, Raab G, Thomson G, et al. Influence of blood lead on the ability and attainment of children in Edinburgh.

skills,[79] word reading,[80] and fine and gross motor development.[81] Additionally, children with average lifetime blood lead levels greater than 15 ug/dl had more attention problems, delinquent and aggressive behavior, social problems, anxiety, depression and withdrawal than children with blood lead levels below 15 ug/dl.[82] Similar results were found for high bone lead levels.[83] For example, Schwartz conducted a meta-analysis and found that for an increase of blood lead from 10 to 20 ug/dl, there was a decrease in IQ of 2.6 points. The studies with average blood lead concentrations of 15 ug/dl or lower had higher estimated decreases in IQ per unit increase in blood lead. Further analysis led him to conclude that there was no evidence of a threshold even down to 1 ug/dl.[84] Another study found that children with average lifetime blood lead levels of less than or equal to 10 ug/dl had 7 points higher IQ scores than children with blood lead levels above 20 ug/dl.[85] Another study in Table 4 shows that blood lead levels also correlate negatively

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Lancet 1: 1221-1226, 1987.

Needleman HL, Gatsonis CA. Low-level lead exposure and the IQ of children. A meta-analysis of modern studies. Journal of the American Medical Association 263: 673-678, 1990.

Needleman HL, Gunnoe C, Leviton A, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. The New England Journal of Medicine 300: 689-695, 1979.

Needleman HL, Geiger SK, Frank R. Lead and IQ Scores: A reanalysis. Science 227, 701-704, 1985.

Schwartz J. Low-level lead exposure and children's IQ: A meta-analysis and search for a threshold. Environmental Research 65: 42-55, 1994.

Tong S, Baghurst PA, Sawyer MG, et al. Declining blood lead levels and changes in cognitive function during childhood. The Port Pirie Cohort Study. Journal of the American Medical Association 280: 1915-1919, 1998.

Tong S, Baghurst P, McMichael A, et al. Lifetime exposure to environmental lead and children's intelligence at 11-13 years: the Port Pirie Cohort Study. British Medical Journal 312: 1569-1575, 1996.

[79] Fulton M, Raab G, Thomson G, et al. Influence of blood lead on the ability and attainment of children in Edinburgh. Lancet 1: 1221-1226, 1987.

[80] Ibid.

[81] Dietrich KN, Berger OG, Succop PA. Lead exposure and the motor developmental status of urban six-year-old children in the Cincinnati Prospective Study. Pediatrics 91: 301-307, 1993.

[82] Burns JM, Baghurst PA, Sawyer MG, et al. Lifetime low-level exposure to environmental lead and children's emotional and behavioral development at ages 11-13 years. The Port Pirie Cohort Study. American Journal of Epidemiology 149: 740-749, 1999.

[83] Needleman HL, Riess JA, Tobin MJ, et al. Bone lead levels and delinquent behavior. Journal of the American Medical Association 275: 363-369, 1996.

[84] Schwartz J. Low-level lead exposure and children's IQ: A meta-analysis and search for a threshold. Environmental Research 65: 42-55, 1994.

[85] Dietrich KN, Berger OG, Succop PA, et al. The developmental consequences of low to moderate prenatal and

with motor development. Six-year old children were divided into four quartiles according to their average lifetime blood lead level. The lowest group had a level of 5-9 ug/dl and the highest group had a level of 17-39 ug/dl. After adjusting for confounding, children with blood lead levels in the lowest quartile exhibited the best motor development and those in the highest quartile exhibited the worst motor development.[86]

These problems continue into adulthood. Needleman et al. collected primary teeth from children over an eleven-year period. He found that after adjusting for confounders, 18 year olds who had previously shed teeth with dentin lead levels greater than 20 parts per million were 7.4 times more likely to drop out of high school, 5.8 times more likely to have a reading disability, had lower grammatical reasoning and vocabulary and had longer reaction times than those with dentin lead levels below 10 parts per million.[87]

Low-level lead exposure is also associated in adults with increased blood pressure,[88] renal impairment,[89] and gout.[90]

5. Alternatives to lead-containing wicks exist.

Cored wicks are used in long-burning scented candles with self-supporting wicks in containers, votives, pillars, and novelties.[91] Metal cores in wicks are used to prevent the wick from bending

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postnatal lead exposure: Intellectual attainment in the Cincinnati lead study cohort following school entry. Neurotoxicology and Teratology 15: 37-44, 1993.

[86]Dietrich KN, Berger OG, Succop PA, et al. Lead exposure and the motor development status of urban six-year old children in the Cincinnati Prospective study. Pediatrics 91: 301-307, 1993.

[87]Needleman HL, Schell A, Bellinger D, et al. The long-term effects of exposure to low doses of lead in childhood: An 11-year follow-up report. The New England Journal of Medicine 322: 83-88, 1990.

[88] De Kort WLAM, Verschoor MA, Wibowo AAE, et al. Occupational exposure to lead and blood pressure: A study in 105 workers. American Journal of Industrial Medicine 11: 145-156, 1987.

Harlan WR. The relationship of blood lead levels to blood pressure in the U.S. population. Environmental Health Perspectives 78: 9-13, 1988.

Harlan WR, Landis JR, Schmouder RL, et al. Blood lead and blood pressure: Relationship in the adolescent and adult US population. Journal of the American Medical Association 253: 530-534, 1985.

Batumen V, Landy E, Maesaka JK, et al. Contribution of lead to hypertension with renal impairment. The New England Journal of Medicine 309: 17-21, 1983.

[89] Batumen V, Landy E, Maesaka JK, et al. Contribution of lead to hypertension with renal impairment. The New England Journal of Medicine 309: 17-21, 1983.

[90] Batumen V, Maesaka JK, Haddad B, et al. The role of lead in gout nephropathy. The New England Journal of Medicine 304: 520-523, 1981.

[91]Wick n'Clip, Inc, 1999Quality Wick Products. Web Site: http: //www.wicknclip.com/types2.html.

and extinguish in the molten wax of the candle. However, alternatives exist, including cotton and paper core-wicks that remain erect during burning.[92] Waxing the wick prior to candle-making constructs a sturdier wick.[93] Leaded wicks also burn more slowly and evenly. However, Krause indicated that 4 of 5 votives (2 in. candles burned in pans) with lead-containing candlewicks burned almost completely in 2 hours despite being advertised to burn for 15 hours.[94] Thus this assertion seems questionable. Finally, in our study, lead-containing wicks were a fraction of those not containing lead for every type of candle proving that the alternatives are viable options.

6. Labeling will not adequately protect candle-users.
Some public health risks are too great to be handled by labeling. This is one. Besides, there are no public health benefits to lead-containing candles. Furthermore, the most at-risk populations, fetuses, infants and young children, do not choose whether a candle is burned. Labeling may ward off some from the danger of burning candles with lead-containing wicks, but it will not protect children, particularly if their parents cannot read or comprehend the warning. The only solution is to completely ban candles containing leaded wicks. Finally, as millions of such candles are sold each year because they are currently on store shelves, you must immediately order a recall of candles with lead-containing wicks.

7. The Consumer Product Safety Act and the Hazardous Substances Act require the Consumer Product Safety Commission to Ban and Recall these products.
The provision of the Consumer Product Safety Act concerning "imminent hazards" posed by products as the basis for the Commission to issue a recall of lead-containing candles operates where products present "imminent and unreasonable risk of death, serious illness, or severe personal injury." 15 U.S.C. §2061(a).

Our study showed that the burning of presently-available lead-wicked candles, with wicks containing from 33% to 85% lead, could result in air lead levels as high as 50 ug/ m^3, well in excess of the 1.5 ug per cubic meter EPA guideline for air lead levels. The Van Alphen study cited on pages 11-12 concluded that burning one high lead candle for three hours could achieve an average 24 hour air lead concentration of 10 ug per cubic meter, more than six times in excess of the EPA's ambient air guideline of 1.5 ug of lead per cubic meter. EPA's own earlier research found that burning candles with lead wicks also resulted in air lead levels similarly in excess of the EPA guideline. That air lead levels resulting from burning such candles can cause a dangerous increase in blood lead levels in children was determined by the aforementioned research of Van Alphen who estimated that burning one lead-wicked candle for three hours per week could raise the blood lead level in children by 3-11 ug/dl above what the levels were before exposure. For many children, this would raise their blood lead levels to well above 10 ug/dl, levels which both the Consumer Product Safety Commission and the Centers for Disease Control

[92] Ibid.

[93] Ibid.

[94] Krause D. Personal communication, February 11, 2000.

and Prevention have found to be dangerous. Additional lead exposure to children can occur from the ingestion of lead-containing dust from the burning of the candles which settles in rooms where candles are burned.

All of these findings clearly demonstrate that lead-based wicks in candles pose an imminent risk of injury. Although the manifestations of exposure to lead may not be immediately apparent--as in the ultimate lowering of IQ in lead-exposed children--the legal standard is imminent risk, not imminent injury.

The provision of the Consumer Product Safety Act pertaining to "banned hazardous products" authorizes the Commission to initiate rulemaking to ban consumer products that present an "unreasonable risk of injury" where "no feasible consumer product safety standard...would adequately protect the public from the risk of injury associated with such product." 15 U.S.C. §2057.

Finally, the Federal Hazardous Substances Act's "imminent hazard" provision, 15 U.S.C. §1261(q)(2), authorizes a ban only as a temporary remedy during the course of regulatory proceedings. However, Section 1261(q)(1) empowers the Commission to classify household products as "banned hazardous substances," as a permanent designation, upon a finding that "the degree or nature of the hazard involved in the presence or use of such substance in households is such that the objective of protection of the public health and safety can be adequately served" only by a ban. 15 U.S.C. §1261(q)(1)(B).

Several years ago, the CPSC asked manufacturers of vinyl miniblinds to stop using lead in the production of these blinds because of the "lead poisoning hazard" they posed to children. The CPSC found that "in some blinds, the levels of dust [from the deterioration of the blinds] was so high that a child ingesting dust from less than one square inch of blind a day for about 15 to 30 days could result in blood levels at or above the 10 microgram per deciliter amount CPSC considers dangerous for young children." (CPSC Press Release, June 25, 1996)

In summary, the Consumer Product Safety Commission has the legal authority, under the Consumer Product Safety Act and the Hazardous Substances Act, to immediately ban the manufacture, stop the importation and order the recall from all channels of commerce of all candles with lead-containing wicks and all lead-containing wicks sold for subsequent incorporation into candles. Any failure to do so will continue to jeopardize the health of millions of people, including tens if not hundreds of thousands of children by exposing them to the completely unnecessary risks of lead poisoning.

Lead-containing wicks are a dangerous product. Through this petition, we have demonstrated that candles with lead-containing wicks are present on store shelves despite the voluntary agreement between the candle industry and the CPSC. We have shown that the candles with lead-wicks emit sufficient lead to exceed EPA air lead standards,[95] HUD floor surface lead

[95]Bridbord K, Medical Officer. Memo to Stanley Greenfield, Assistant Administrator for Research and

concentrations[96] and the CPSC's own recommendations for maximal lead intake by children.[97] Furthermore, we have demonstrated that the concentrations attained by burning these candles can raise children's blood lead levels sufficiently to impair intelligence and cause behavioral problems.[98] Finally, we have shown that 3% of candles have high lead content. In 1974, Russell Train, then Administrator of EPA, stated "Inhabitants of homes in which lead-wicked candles are burned could be exposed to substantial incremental quantities of lead which, if continued on a regular basis, would pose a significant risk to health especially among children with already elevated lead body burdens. In my opinion candles represent an unnecessary incremental source of lead that can readily be controlled."[99] His concern is as relevant now as it was then.

Development, and Vaun A. Newill, Special Assistant to the Administrator: Hazards of burning candles with lead. US EPA, Research Triangle Park, December 14, 1973.

Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

Code of Federal Regulations. Title 40--Protection of Environment, Chapter 1--Environmental Protection Agency, Part 50, Sec 50.12 National primary and secondary ambient air quality standards for lead.

[96] Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

http://www.hud.gov:80/lea/leach1.pdf; Chapter 1: Introduction. Legislative Basis and Relationship to Federal Programs and Regulations. In The Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing, 1995.

[97] Consumer Product Safety Commission. CPSC Staff report on lead and cadmium in children's polyvinylchloride (PVC) products. Page 3. 21 November 1997.

Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

[98] Bridbord K, Medical Officer. Memo to Stanley Greenfield, Assistant Administrator for Research and Development, and Vaun A. Newill, Special Assistant to the Administrator: Hazards of burning candles with lead. US EPA, Research Triangle Park, December 14, 1973.

Krause JD. Characterization of scented candle emissions and associated public health risks. Thesis. Department of Environmental and Occupational Health. University of South Florida. August 1999.

Van Alphen M. Emission testing and inhalational exposure-based risk assessment for candles having Pb [lead] metal wick cores. Science of the Total Environment. 243-244: 53-65, 1999.

Consumer Product Safety Commission. CPSC Staff report on lead and cadmium in children's polyvinylchloride (PVC) products. Page 2. 21 November 1997.

[99] Letter to Mr. Simpson, Chairman of CPSC, from Russell Train, Administrator of EPA, March 1974.

The Consumer Product Safety Commission has a clear mandate to protect the American public from these hazardous products.

Sincerely,

Howard L. Sobel, M.D., M.P.H, M.S.
Research Associate

Sidney M. Wolfe, M.D.
Director

Peter Lurie, M.D., M.P.H.
Deputy Director
Public Citizen's Health Research Group

Table 1. Lead content of lead-containing candles purchased for February, 2000 Health Research Group candle study.

Total lead in wick (ug)	Total lead emitted from wick (ug)[100]	Average 24-hour Air lead levels (ug/m³)[101]	Multiples of EPA Ambient Air Lead Levels of 1.5 ug/dl
39400.0	7880.0	19.3	13
68058.0	13611.6	25.0	17
117935.5	23587.1	43.3	29
66956.5	13391.3	49.2	33
32112.9	6422.6	17.2	11
37795.3	7559.1	22.2	15
62152.2	12430.4	22.8	15
25785.7	5157.1	15.2	10
23618.4	4723.7	13.9	9
		Average:	17
		Median:	15

[100] Assumes that only 20% of lead in candlewicks is emitted. In previous studies, the actual amount emitted into the air ranged from 20 to 35%.

[101] First, the amount of lead emitted per cm was calculated. We assumed the burn rate was 2 cm/hour and that people burn candles only for 3 hours and then extinguish the candle. Other assumptions include that the ventilation rates are 25% per hour and that the room dimensions are 15 ft. x 15 ft. x 8 ft which converts to 51 m³. We then calculated lead concentrations for each of 24 hours.

For the first hour, the concentration was the lead/cm times 2 cm/hour times 20% (giving the total lead emitted during the first hour) divided by 51 m³, the total volume of the room. We then multiply this concentration by 0.75, because 25% is exchanged per hour.

For the second and third hour, it was 75% of the lead concentration at the end of the previous hour plus the newly emitted lead which is the lead/cm times 2 cm times 0.2 divided by 51 m³, as before.

For the fourth to 24th hour, because the candle was extinguished, the lead concentrations decrease by 25% of the value at the end of the previous hour each hour.

Finally, the hourly lead concentration were added and divided by 24 hours to determine the average concentration.

A Microsoft Excel Spreadsheet was used to perform these calculations.

Table 2. Comparison of prenatal exposure to low-level lead with clinical effect.

Clinical effect	Lead Exposure Level	Study finding
In Utero Exposure Placental lead in: Normal Birth Miscarriage Early Neonatal Death	Placental lead: 0.93 ug/g 1.45 1.73	Placental lead concentration is lower in placentas of children who survived the neonatal period than those who did not.[102]
Premature birth	> 14 ug/dl vs. <8 ug/dl maternal blood lead concentration at delivery.	4.4 times the risk of premature delivery in high compared to the low blood lead group.[103]

[102]Wibberley DG, Khera AK, Edwards JH, et al. Lead levels in human placentae from normal and malformed births. Journal of Medical Genetics 14: 339-345, 1977.

[103]Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

Decreased mental or cognitive development	<3 ug/dl, 6-7 ug/dl, and >10 ug/dl umbilical cord blood	Highest cord blood lead level group performed 4-8 points lower on the Bayley Scale of Infant Development-Mental Development Index with incremental increase of umbilical cord blood level. [104]
	4.5 ug/dl (mean) in utero blood lead, maximum <30 ug/dl	For each 1-ug/dl increase in blood lead level, the MDI decreased 0.34 points (9.2 points across the range). [105]

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Bellinger DC, Leviton A, Waternaux C, et al. Methodological issues in modeling the relationship between low-level lead exposure and infant development: Examples from the Boston lead study. Environmental Research 38: 119-129, 1985.

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[105] Dietrich KN, Krafft KM, Bornschein RL, et al. Low-level fetal lead exposure effect on neurobehavioral development in early infancy. Pediatrics 80: 721-730, 1987.

Table 3. Comparison of post-natal exposure to low-level lead with clinical effect in preschoolers.

Lead Exposure Level	Age	Effect
14-22 ug/dl blood level. Compares lowest quartile to highest.	2	1.9 point decrease in scores of the Mental Development part of the Bayley Scales of Infant Development for every 10 ug/dl increase in blood lead over the range of 14-22 ug/dl. [106]
10, 18.4, 29.9 ug/dl integrated postnatal blood lead.	2	1.6 point decrease in scores of the Mental Development part of the Bayley Scales of Infant Development for every 10 ug/dl increase in blood lead for levels <30 ug/dl. [107]
0-9.9 vs. 10-24.9 ug/dl blood lead.	1-3	Higher blood lead group had 6.2 points lower scores of the Mental Development part of the Bayley Scales of Infant Development than the lower blood group. [108]
5-57 ug/dl blood lead	4	Incremental increases in blood lead level from 10 to 30 ug/dl corresponds to a decrease of 7.2 units of the General Cognitive Index. Memory also impaired. [109]

[106] Baghurst PA, Robertson EF, McMichael AJ, et al. The Port Pirie Cohort Study: Lead effects on pregnancy outcome and early childhood development. Neurotoxicology 8: 395-402, 1987.

[107] Wigg NR, Vimpani GV, McMichael AJ, et al. Port Pirie Cohort Study: Childhood blood lead and neuropsychological development at age two years. Journal of Epidemiology and Community Health 42: 213-219, 1988.

[108] Mendelsohn AL, Dreyer BP, Fierman AH, et al. Low-level lead exposure and cognitive development in early childhood. Journal of Developmental and Behavioral Pediatrics 20: 425-431, 1999.

[109] McMichael AJ, Baghurst PA, Wigg NR, et al. The Port Pirie Cohort Study: Environmental exposure to lead and children's abilities at the age of four years. The New England Journal of Medicine 319: 468-475, 1988.

Table 4. Comparison of post-natal exposure to low-level lead with clinical effect in school-age children

Lead Exposure Level	Age	Effect
>24 PPM vs. <6 PPM lead in dentin	7-8	Higher lead levels corresponded to poorer performance on test of IQ, auditory and verbal processing, attention, and teachers behavioral rating. (1st and 2nd graders).[110]
6-100 ug/dl blood lead lead 2.4 to >150 PPM tooth lead levels	Meta-analysis	11/12 studies employing multiple regression found that increasing blood or tooth lead levels were associated with lower IQ.[111]
10 groups with mean blood lead levels from 5.6-22.1 ug/dl	6-9	Overall ability and attainment, and specifically, number skills and word reading decreased with increasing blood lead concentration.[112]
0-10, >10-15, >15-20, >20 ug/dl average lifetime blood lead.	6.5	IQ is 7 points lower in the lowest than the highest lead group.[113]
7.5-30 ug/dl average lifetime lead level	7	IQ decreases approximately 5 points for increases of blood lead from 10 to 30 ug/dl.[114]
11-18.6 ug/dl average lifetime lead level	11-13	Cognitive deficits in children whose blood lead concentration was high improve only partially with a subsequent decline of blood lead level.[115]
11-18.6 ug/dl average lifetime lead level	11-13	Mean IQ decreased 3 points for an increase in blood lead level from 10 ug/dl

[110] Needleman HL, Gunnoe C, Leviton A, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. The New England Journal of Medicine 300:689-695, 1979.
Needleman HL, Geiger SK, Frank R. Lead and IQ Scores: A reanalysis. Science 227, 701-704, 1985.

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[112] Fulton M, Raab G, Thomson G, et al. Influence of blood lead on the ability and attainment of children in Edinburgh. Lancet 1: 1221-1226, 1987.

[113] Dietrich KN, Berger OG, Succop PA, et al. The developmental consequences of low to moderate prenatal and postnatal lead exposure: Intellectual attainment in the Cincinnati lead study cohort following school entry. Neurotoxicology and Teratology 15: 37-44, 1993.

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[115] Tong S, Baghurst PA, Sawyer MG, et al. Declining blood lead levels and changes in cognitive function during childhood. The Port Pirie Cohort Study. Journal of the American Medical Association 280: 1915-1919, 1998.

[116] Tong S, Baghurst P, McMichael A, et al. Lifetime exposure to environmental lead and children's intelligence at

		to 20 ug/dl.[116]
>15 vs. <15 ug/dl lifetime average lead level.	11-13	Higher lead levels were associated with higher behavioral problem score. Boys had higher attention problems, delinquent behavior, and aggressive behavior. Girls had these and additionally had higher social problems, anxiety/depression, and withdrawal.[117]
5-9, 9-12, 13-17, 17-39 ug/dl average lifetime blood lead	6	Fine and gross motor development decrease with increasing average blood lead level. (6 year olds).[118]
Mean blood lead levels of 11 -23 ug/dl	Meta-analy sis	An increase from 10 to 20 ug/dl reduces IQ by 2.6 points. There is no threshold. Decreases in IQ continue to below 5 ug/dl.[119]
Quintiles according to Bone lead levels by backscattered Xray peak intensity vs. standards.	7	Higher bone lead levels were associated with higher risk of antisocial and *delinquent behavior.*[120]

11-13 years: the Port Pirie Cohort Study. British Medical Journal 312: 1569-1575, 1996.

[117] Burns JM, Baghurst PA, Sawyer MG, et al. Lifetime low-level exposure to environmental lead and children's emotional and behavioral development at ages 11-13 years. The Port Pirie Cohort Study. American Journal of Epidemiology 149: 740-749, 1999.

[118] Dietrich KN, Berger OG, Succop PA. Lead exposure and the motor developmental status of urban six-year-old children in the Cincinnati Prospective Study. Pediatrics 91: 301-307, 1993.

[119] Schwartz J. Low-level lead exposure and children's IQ: A meta-analysis and search for a threshold. Environmental Research 65: 42-55, 1994.

[120] Needleman HL, Riess JA, Tobin MJ, et al. Bone lead levels and delinquent behavior. Journal of the American Medical Association 275: 363-369, 1996.

NMHC National Multi Housing Council

National Apartment Association

February 23, 2000

The Honorable Ann Brown
Chairman
U.S. Consumer Products Safety Commission
4330 East West Highway
Bethesda, Maryland 20814

2000 FEB 29 A 9: 20
CPSC/OFFICE OF THE SECRETARY

Dear Chairman Brown,

The National Apartment Association (NAA) and the National Multi Housing Council (NMHC) represent the owners, managers, developers and financiers of the majority of the nation's multifamily rental housing units. Our members bear a strong commitment to safe, affordable and accessible housing and as such, respectfully ask that you ban the use of lead in candle wicks based on the hazard they pose to health, particularly that of children.

Scientific analyses indicate that candles manufactured the in the United States and China often contain wicks that have lead cores. When these candles are burned, a significant portion of the volatized lead is released into the room's airspace resulting in toxic levels of lead exposure. According to a study conducted by Professor Jerome Nriagu, of the University of Michigan in Ann Arbor, the burning of candles containing lead wicks, under conditions of normal use, can result in more than a 30-fold increase over the airborne levels considered as be safe by the U.S. Environmental Protection Agency (EPA).[1]

Additional information on this matter has been published by Dr. Mike van Alphen in the journal, *The Science of the Total Environment*, (attached) which indicates that the lead which is released as a result of candle burning is in a chemical form which is highly biologically available to those who come in contact with the lead particles. According to this analysis, not only is the lead in its aerosolized form likely to pose a significant poisoning potential for children but the lead particles which will ultimately settle out as house dust, will pose a second source of exposure to residents of homes in which these candles are used.

Our industry has worked closely with CPSC, EPA, the U.S. Department of Housing and Urban Development, the U.S. Occupational Safety and Health Commission to bring about the end of childhood lead poisoning. Recent data from the U.S. Centers for Disease Control and Prevention finds that the nation

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1 Quoted by Reuters newservice; manuscript submitted for publication.

is well on the way to eliminating childhood lead poisoning. In fact, we understand that federal officials plan to announce that childhood lead poisoning could be vanquished by 2010 as a result of strong federal policies which have sought to control the use of lead.

We must not permit this public health success story to be compromised by the sale and use of candles with lead-containing wicks. There are many alternative materials which could be substituted for the lead compounds in wicks which would still permit the candle to be burned without creating toxic lead vapors and dust.

As property owners, we are subject to laws on the local, state and federal level which require that in many circumstances, we test our properties for "lead hazards." According to guidance published in 1995 by the EPA, in advance of the issuance of a rule still pending under the Toxic Substances Control Act, certain levels of lead in house dust are considered to be "lead hazards." Once a "lead hazard" is identified, property owners must act (pursuant to other controlling authorities) to abate the hazard. Our efforts to maintain a lead safe residential environment for our residents is significantly compromised by the use of consumer products which release harmful levels of toxic lead.

Sincerely,

Eileen Lee

Eileen Lee Ph.D.
Vice President of Environment

Attachment

cc: Honorable C. Browner
Honorable A. Cuomo

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Emission testing and inhalational exposure-based risk assessment for candles having Pb metal wick cores

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Abstract

Segments of seven candles with wicks having a Pb metal core have been tested in a purpose-built combustion chamber to assess air Pb emissions. Emissions were collected on glass fibre filters that have been digested in concentrated HNO_3 and analysed by flame atomic absorption spectroscopy (FAAS). Despite an indication of a bimodal distribution in Pb emission rates, and a range from 450 to 1130 μg Pb/h, the mean rate from the seven candles was 770 μg Pb/h. The 38-cm long candles are, on average, capable of emitting 104 000 μg of Pb into the air over ~ 127 h. A mean value of 20% of the Pb metal in the wick consumed by the candle is emitted into the air, the remainder appears to accumulate at the base of a molten wax-pool adjacent to the wick. Individual Pb-bearing particles from the combustion of candles were observed in a field emission scanning electron microscope (FESEM) to have a diameter of 1 μm or less. The emission from the candles has been analysed by X-ray diffraction (XRD) and identified as Sodium Lead Carbonate Hydroxide [$NaPb_2(CO_3)_2OH$]. This compound, being a Pb carbonate, is likely to be easily absorbed in the lungs and gastrointestinal tract. Risks associated with inhalational exposure have been assessed after determining indoor lead in air (PbA) concentrations. Given a lack of information on the duration of use of candles, a range of scenarios from worst possible case to daily and weekly burning regimes are evaluated. Detailed evaluations of PbA are based on the emission from a single candle at rates of 500 and 1000 μg Pb/h, room volumes of 25 and 50 m^3, durations of emission of 1.5, 3 and 6 h and air infiltration rates of 0, 0.25, 0.5, 0.75 and 1.0 air volume changes per hour (ACH). A candle burnt for 3 h at 1000 μg/h in a 50 m^3 room having poor ventilation at 0.25 ACH is estimated to yield a 24-h average lead in air concentration of 9.9 μg/m^3 with a peak PbA value of 42.1 μg/m^3. Daily exposure to such candle burning where children spend 80% of their time indoors is likely to elevate PbB in children by a minimum of 24 to 40 μg/dl, according to the PbB:PbA relationship of Brunekreef, 1984 (The relationship between air lead and blood lead in children: a critical review). Estimating child Pb uptake from first principles using a range of exposure factors, a child would obtain some 85 to 127% of the provisional tolerable weekly Pb intake (PTWI) from such daily exposure. Child blood lead levels could readily exceed levels of 10 μg/dl, largely due to exposure to emissions from burning Pb wick core candles for several hours once per week. The regular burning of multiple candles in small, poorly ventilated spaces could readily be associated with clinical Pb poisonings

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and death. High levels of exposure could occur with Pb metal core wick candles in less developed countries where candles are used on a daily basis for indoor lighting purposes in small dwellings. Prolonged burning of candles may occur in religious and in ceremonial circumstances or restuarants where they may be of particular concern. On the basis of the limited investigation carried out, candles having a wick with a Pb metal core have the potential to present highly unacceptable and avoidable risks to human health.

Keywords: Candles; Wick; Pb; Lead; Combustion; Lead in air; $NaPb_2(CO_3)_2OH$; Indoor air quality; Inhalational exposure; Risk assessment

1. Introduction

A range of candles sold in Adelaide, South Australia and manufactured in the Peoples Republic of China have metal cores to a fabric-based candle wick sheath.

The risks associated with the candles were considered to relate mostly to any potential for air emission of metal fumes and subsequent inhalational exposure. A proportion of metal particles released into the air could be deposited indoors as dust and then pose a hazard particularly to young children due to the potential for ingestion owing to normal hand-to-mouth and mouthing behaviours.

The potential for children to access wicks containing hazardous metal or metal combustion products such as metal oxides is a related issue.

A survey of the metals in wick cores encountered a range of metals and metal alloys in the candle wicks, but the investigation here evaluates a relatively tall 38-cm long candle form that had Pb metal wick cores.

Particular concerns exist in relation to Pb exposure of women of reproductive age, pregnant women and young children. There is a need to prevent such exposures (Alliance to End Childhood Lead Poisoning and Environmental Defence Fund, 1994; NSW LRC, 1997; Silbergeld, 1997). This initial risk assessment must focus on the most susceptible group namely children. Blood Pb levels (PbB) of 10 $\mu g/dl$ and of 150 $\mu g/dl$ represent, respectively, a currently accepted concentration that child-populations should preferably not exceed and a level at which death is highly likely (NSW LRC, 1997).

One unknown is the frequency and duration of burning of candles and initially precautionary estimates of risk may be warranted to account for this and other uncertainties. A wide range of possible exposure scenarios including worst case scenarios need to be evaluated so as to account for a wide range of conditions of use of candles. The relatively low cost of these particular candles makes both extensive and repeated use possible. High levels of exposure may occur with this generic type of metal core wick candle in less developed countries where candles are used on a daily basis for indoor lighting purposes in small dwellings. Prolonged burning of candles may occur in religious and in ceremonial circumstances.

1.1. Risk assessment

The determinants of inhalational exposure include the emission rate from the candle, numbers of candles burnt, the duration and frequency of burning of candles, the volume of the room or house, the infiltration of diluting air and the duration of exposure of home occupants. In addition the risks will depend on the particle size of any emitted materials and propensity for deposition in the lung and the solubility of any such Pb compounds.

Limited guidance is available from existing lead in air (PbA) standards. In Australia the recommended maximum outdoor ambient lead in air level is 1.5 μg Pb/m^3 (Brown, 1997) and the standard for occupational exposure (NOHSC, 1995) is 150 μg Pb/m^3. These exposure standards are 90-day running means and 8 hour averages respectively. The occupational exposure standard is neither appropriate for children, women of childbearing age nor indoor residential exposures.

A situation-specific risk analysis is required for an emission source such as a candle inside a house. In the case of short-term exposures, the uptake via inhalation for short exposure episodes can be estimated for children using the following exposure factors as a guide:

- children from 3 to 5.9 years old have a respiration rate of 6 to 10 m^3/d (Langley and Sabordo, 1996 p. 178);
- the retention of fine particles in the lung is ~ 35 to 50% (Langley and Sabordo, 1996 p. 179; IPCS, 1995);
- the solubility of Pb phases needs to be taken into account;
- children spend ~ 90% of the time indoors at 7 months to ~ 79% at 2.5 years (Brinkman et al., 1999); and
- mean PbA values and exposure durations are required.

The World Health Organisation has a provisional tolerable weekly intake (PTWI) for children at 25 μg Pb/kg body weight (Galal-Gorchev, 1993). Given assumptions regarding Pb uptake being ~ 50% of intake by ingestion in children (Carrington et al., 1993; IPCS, 1995) the PTWI equates to an uptake of 12.5 μg Pb/kg body weight per week. For 10 and 15 kg children, the PTWI corresponds with a weekly uptake of ~ 125 and 188 μg Pb and the daily uptake of ~ 18 and 27 μg of Pb.

Other means of estimating PbB is to use the relationship between median blood lead levels of populations and outdoor PbA (Chamberlain, 1983). An additional 1.92 μg Pb/dl for every 1.0 μg Pb/m^3 in air may be expected for children (IPCS, 1995). Where children have hand-to-mouth exposures to deposited dusts in addition to inhalational exposures, the PbB:PbA relationship for populations suggest increases of 3–5 μg Pb/dl for every 1.0 μg Pb/m^3 in air (Brunekreef, 1984; adopted in IPCS, 1995), and this is a more appropriate ratio to use in this work.

The PbB:PbA relationship is between the PbB of populations of young children and outdoor average ambient PbA concentrations. However, children can spend 79 to 90% of the time indoors and indoor PbA is usually in the range of 30 to 80% of outdoor PbA (Kutlaca, 1998). The above PbB:PbA relationship of 3 to 5 μg Pb/dl for every 1.0 μg Pb/m^3 in air will understate the Pb exposure of young children where there is a potent air Pb emission source indoors.

1.2. Air infiltration rates in houses

Mean air infiltration rates in New Zealand, Australia and Denmark commonly approach 0.5 air volume changes per hour (ACH) (Kvisgaard and Collett, 1990; Bassett, 1992, p. 75; Biggs et al., 1987). Air infiltration into houses is greater in exposed settings and in high outdoor wind speed conditions (Bassett, 1983; Biggs et al., 1987). Under low wind speed conditions typical of night time conditions, the air infiltration rate trends to some value between 0.23 and 0.6 ACH (Biggs et al., 1987). In occupied houses, base air infiltration rates of < 0.2 ACH can be measured during continuous monitoring (Kvisgaard and Collett, 1990) in association with peak-levels where the air infiltration rate can be ≫ 1 ACH. A great deal of variation in air infiltration can be expected in occupied houses that may not be well represented by mean air infiltration rate data.

1.3. Contaminant dilution owing to air infiltration

Indoor air quality risk assessments can employ models such as described by Ekberg (1994) or Sparks (1997) to model air concentrations over time, so as to model short-term and daily exposures.

2. Methods and materials

The tall-form candles tested had a white wax colour and were 38 cm long and from 4.8 cm wide at the top to 5.5 cm wide at the base. Samples of available wick core from 1.5 to 2.5 cm long were removed from the top of the candle so as to determine the weight of metal per unit length (μg/cm) and for the purpose of analysis of the metals present. Lengths of metal core were weighed to 0.0001 g using a Sartorius A200S

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balance and measured using a steel ruler divided at 0.05 cm intervals with the aid of a $\times 10$ power hand lens.

Metal core lengths and sections cut by a stainless steel scalpel were placed uncoated on carbon-based adhesive stubs and both observed in a scanning electron microscope (SEM) and analysed qualitatively by energy dispersive analysis (EDX) at 20 kV (Philips XL20). Analyses of 100 s live time and count rates greater than 1000 counts per second were used.

A sampling chamber was designed and constructed so as to test particulate metal air emissions from burning candles. The vertically oriented stainless steel chamber has an internal diameter of 30 cm and length of 82 cm with a platform at the base to hold a burning candle. Ambient air was filtered on the way into the base of the chamber through a 20.3×25.4 cm Gelman type AE glass fibre filter and combustion products were collected on a similar filter at the top of the chamber. Air was pumped from the chamber at a rate of 17 ± 1 l/min, producing a nominal air speed of 0.4 cm/s. The flow rate used did not appear to cause appreciable disturbance of the candle flame and maintained temperatures on the exhaust head at < 5–10°C above ambient air temperature. The flow rate through the diaphragm pump (Dynavac OD1) and chamber was unregulated and measured on the exhaust side of the pump before and after the emission tests using a dry gas meter (Toyo, ML2500). Moisture condensation in the vacuum line was captured in a moisture trap installed before the pump and insulation was added to the chamber to minimise moisture condensation in the sample chamber. A circular plate fitting in the chamber with a clearance of 1 cm covered an opening above the inlet filter so that any deposition within the chamber could not directly contaminate the inlet filter. The chamber was fully disassembled and cleaned between samples.

Before and after chamber burning tests, the length of candles and exposed wick were measured and the mass of wax loss measured. The seven lengths of candle from different candles tested in the chamber ranged from 16 to 38 cm with five segments at 18 to 22 cm long. The seven candle sections tested were approximately circular in cross-section with a mean base diameter of 5.2 cm (range 5.1 to 5.5 cm), with the wick being central at the top and ranging from 1.7 to 2.4 cm from the candle edge at the base (mean = 2.0 cm). Two of the candle segments tested had 0.5 cm diameter voids extending for at least several centimetres at the centre of the candle section base. Voids have been measured at 0.5 cm diameter and > 9.5 cm length at the centre of segments of the candle-type tested.

The inlet and chamber outlet filters have been analysed for Pb. The filters were cut in half and digested in concentrated HNO_3 and determined for Pb by flame atomic absorption spectroscopy (FAAS). A blank half-filter and two spiked half-filters containing 0.2517 and 0.2697 g of standard reference material (SRM) 2711 (NIST, 1993) were also submitted for analysis. In addition five aliquots of SRM 3172a (100 μg/ml) were prepared based upon dilution at 2 ml into 100 ml; although 5 ml is the pipette volume recommended (NIST, 1996).

A section of filter from two samples was sampled for the purpose of X-ray diffraction (XRD) analysis to determine the nature of any crystalline compounds deposited on the filter on the exhaust end of the chamber. The XRD analysis (Philips PW 1011 machine) was operated at 36 kV and 28 mA producing Cobalt Kα radiation. The samples were analysed over an angular range from 5 to 65° 2θ, at 0.5° 2θ per minute with a time constant of 4 s and a chart recorder speed of 0.5 cm/min. The full-scale deflection was set to 1×10^3 counts per second.

An analysis of combustion material collected on the filter at the exhaust of the chamber was carried out by EDX in a field emission scanning electron microscope (FESEM) at 10 kV (Philips XL30) to support the XRD determination and evaluate the particle size of emitted materials in a preliminary manner.

The diameter of metal wick cores have been determined in the SEM and also measured using micrometers.

This paper reports specifically on the results from seven candles having Pb metal wick cores, where the candles were burnt and exhaust fumes sampled for 43 to 100 h.

Air concentration estimation

An initial assessment of the impacts of any Pb emissions from candles is by way of assessing the possible maximum air concentrations of metals in residential settings given no air dilution. Five nominal categories of small to large 'room' volumes for residential settings at 25, 50, 100, 200 and 400 m^3, are used for this worst-case scenario. Many entire houses would have an occupied living-space volume of < 200–400 m^3 (Biggs et al., 1986). Durations of burning from 1.5, 3, 6, 12 and 24 h are used. This simplistic assessment strategy has limitations in relation to risk assessment but is important for providing a range of maximum PbA concentrations.

Using Ekberg (1994) and Sparks (1997) as a guide, a model has been assembled to produce a trajectory of PbA over time. An Excel spreadsheet having 2880 lines of calculation accounts for Pb emission and PbA dilution due to air infiltration over 30 s intervals over 24 h. The model assumes the following:

- one candle burning episode per day;
- dilution due to air infiltration with no deposition;
- uniform mixing;
- estimates additional PbA only (e.g. assumes dilution air = 0 μg Pb/m^3);
- Pb emission rate is a variable; based on results of this work (μg Pb/h);
- two small room size options of 25 and 50 m^3;
- emission duration options of 1.5, 3 and 6 h; and
- air infiltration rate options of 0, 0.25, 0.5, 0.75 and 1.0 air volume changes per hour.

Integrating the air concentration/time curves is used to give mean air concentrations that would reflect daily use of candles.

3. Results

3.1. Pb in wick cores

Energy dispersive X-ray spectroscopy of seven samples of metal wick core indicate the presence of Pb peaks only and the absence of well-formed peaks, for other elements, that would indicate that any other elements were unlikely to be present at levels greater than 1 to 5 wt.%.

The seven Pb wick cores ranged in diameter from 340 to 490 μm with a mean diameter of 400 μm, the cross-sections were rounded but not circular, one sample was teardrop shape in cross-section. The weight of metal (Pb) in the wick cores ranged from 11 200 to 18 100 μg/cm with a mean of 13 700 μg/cm.

Other metal wick cores of Zn and a range of Pb/Sn alloys have been encountered from candle types other than those tested here. These metal

Table 1
Candle Pb emission rates from combustion testing

Sample number	Candle test duration (h)	Inlet filter Pb concentration	Pb in the half filter sample (μg)	Amount of Pb on filter during sample interval (μg)	Rate of Pb emission (μg Pb/h)
9904001	50	< 3	12 670	25 340	510
9904002	100	7.6	49 380	98 760	990
9904010	50	< 3	11 290	22 580	450
9904011	43–45*	< 2	12 530	25 060	560–580
9904024	52	2.7	23 790	47 580	920
9904025	50	3.0	20 800	41 600	830
9904032	50	< 2	28 190	56 380	1130

*Approximate value owing to all of the candle test segment being consumed.

cores had diameters from 350 to 850 μm, with the larger diameter metal wick cores having a circular or irregular central void and the appearance of a heavy-walled tube. It is possible that the metal cores seen in candles are similar to wire used in electrical soldering. There are indications also that the candlewicks were manufactured in a manner similar to sinking 'lead-lines' used for trout fishing. Some candles were seen to have a core with the appearance of nylon as per floating 'dry-fly' fishing line. The candlewicks in some cases appeared to have been placed in holes made by a hot wire as opposed to having been cast in place in the wax.

3.2. *Characteristics of exhaust filters and candles after chamber burning tests*

The chamber tests were carried out over intervals generally at 50 h and up to 100 h as summarised in Table 1. One candle segment was fully consumed and extinguished prior to completion of a scheduled 50-h sample run and the time of burning is estimated at 44 ± 1 h from an observation of elevated temperature of the sample chamber at 43 h and the time of inspection of the cooled chamber at 45 h.

After burning is completed, metallic droplets and black charred wick material having patches of yellow encrustation are observed at the bottom of a molten wax pool, adjacent to the wick. This is where most of the Pb in the wick core accumulates.

The filters on the chamber exhaust for most samples appeared heavily loaded with an even cream-yellow colour; the exception was a black filter surface where the candle was extinguished while the air was still flowing. Particulate on the chamber inlet filters varied from faint to a visible loading for the sample that ran for 100 h. Wipes of the inside of the chamber did not reveal visible evidence of particulate deposition, this observation has not been validated by any further analysis however.

3.3. *FAAS analysis of candle fume samples*

Two half-filter samples spiked with 0.2517 and 0.2697 g of SRM 2711, at 1162 μg/g Pb contained 293 and 313 μg of Pb, respectively. The concentrated HNO_3 digest and FAAS analysis recovered 274 and 315 μg of Pb, demonstrating an analytical recovery of 93.5 and 100.6%. Aliquots of SRM 3172a containing a nominal 2 μg Pb/ml returned values of 1.96, 2.03, 1.98, 2 and 2.01 μg Pb/ml.

The seven tall-form candle samples burnt in the combustion chamber returned results by FAAS on half-filter segments of 11 290 to 49 380 μg Pb per half filter as per Table 1. The rate of emission of Pb from the seven candles ranged from 450 to 1130 μg of Pb/h with a mean of 770 μg Pb/h. There are indications that the Pb emission rate data may be bimodal with emission rate means of 510 and 970 μg Pb/h.

Table 2
Proportion of Pb in wick transferred to air and individual candle length and wick data

Candle no.	9904001	9904002	9904010	9904011	9904024	9904025	9904032
Pb in wick (μg Pb/cm)	12 800	11 200	13 100	18 100	14 700	13 400	12 400
Estimated Pb consumed during candle burning (μg)	129 000	358 000	186 000	329 000	226 000	214 000	172 000
Lead on filter (μg)	25 340	98 750	22 580	25 060	47 570	41 590	56 380
Proportion of candle wick Pb transferred to air (%)	19.6	27.6	12.1	7.6%	21.0	19.4	32.8
Length of wick burnt (cm)	10.1	32.0	14.2	18.2	15.4	16.0	13.9
Burn rate (cm/h)	0.20	0.32	0.28	0.40–0.42	0.30	0.32	0.28

Given the candle length at 38 cm, a mean burn rate of 0.30 cm/h (subject to a nominal air speed of 0.4 cm/s), a mean metal wick-core mass of Pb of 13 700 μg/cm and a mean rate of emission to air of 20% of the wick metal mass (Table 2); individual candles could readily emit 104 000 μg of Pb into the air over ~ 127 h.

3.4. X-ray diffraction analysis

Analysis by XRD of segments of two filters (9904001 and 9904010) containing fumes from the 50 h of burning of tall-profile candles identified a single dominant Pb rich phase; Sodium Lead Carbonate Hydroxide [$NaPb_2(CO_3)_2OH$] previously characterised by Brooker et al. (1983). Ten peaks for $NaPb_2(CO_3)_2OH$ were identified on XRD charts for both samples, for the angle scanned between 5 and 65° 2θ.

3.5. Confirmation of sodium lead carbonate hydroxide by EDX analysis

Inspection of a carbon coated segment of one of the exhaust glass fibre filters (9904001) using the backscattered electron detector on a Philips XL30 FESEM at a 10 kV accelerating voltage readily identified 'high mean atomic number' particles on the filter. What was observed in backscattered electron mode followed by secondary electron imagery was consistent with the particulate on the filter being a single Pb-rich phase. Discrete particles at 0.5 to 1.0 μm diameter were seen at 1935 X-magnification on the filter fibres but more fine grained material was not clearly resolved probably due to the carbon coating of the sample. Energy dispersive point analysis at 10 kV on an apparently clean 1.8 μm diameter filter fibre indicated the presence of C, O, Na, Mg, Al, Si, Ca and minor Pb. An area analysis on a 4 μm diameter particle cluster indicated much increased levels of Na and Pb consistent with the particles being $NaPb_2(CO_3)_2OH$.

4. Discussion

4.1. Uncertainty in candle Pb emission rates

The candles tested emitted Pb at a mean rate of 770 μg/h however, the data appears to be bimodally distributed with means at 510 and 970 μg/h. Whether these rates apply equally to short burning episodes has not been determined. The emission rate is suggested to be subject to variability due to the mass of Pb per unit length of wick, variation in wax composition and burning temperature and variation in the rate of burning of candles. Factors affecting the candle-burning rate may include:

- whether the candle is perfectly vertical;
- the air-flow around the candle:
- variation in wax composition;
- variations in diameter and shape of candles:
- any offsets of the wick from the candle centre: and
- void spaces in the candle wax.

Table 3
Maximum PbA calculations for a worst-case scenario

Volume of living space (m^3)	Duration of burning of one candle at 1130 μg/h				
	1.5 (h)	3 (h)	6 (h)	12 (h)	24 (h)
Maximum lead in air concentrations for each room volume — candle burn duration (μg Pb/m^3)					
25	68	136	271	542	1085
50	34	68	136	271	542
100	17	34	68	136	271
200	8.5	17	34	68	136
400	4.2	8.5	17	34	68

4.2. Maximum air concentrations expected

Estimates of maximum Pb in air values are available in Table 3 and are based upon a peak emission rate encountered at 1130 μg Pb/h. This worst case scenario assumes a lack of air infiltration and five nominal categories of living space volume at 25, 50, 100, 200 and 400 m^3, and burning times of 1.5, 3, 6, 12 and 24 h.

Assuming a lack of dilution, air PbA concentrations could build to a maximum level at the end of the candle-burning period and be maintained for relatively long periods of time. In the absence of appreciable air infiltration, such elevated levels in air would ultimately be reduced due to particle deposition. Values of PbA exceeding occupational lead exposure levels are possible, and Pb exposures may be high. The zero air infiltration/worst possible case scenario may not be relevant to most exposure settings but must be recognised as potentially having severe consequences particularly for young children.

4.3. Estimating mean 24 h PbA in residential settings and PbB based on repeated exposure

The worst possible case scenario may not adequately characterise the more usual exposures to Pb fume from these candles with Pb wick cores in ventilated housing settings. A more long-term exposure pattern may also need to be considered so as to estimate PbB.

Estimation of the trajectory of PbA over time here is based on the following conditions:

- one candle burning episode per day, using one candle;
- dilution of PbA due to air infiltration with no particulate deposition;
- uniform air mixing;
- assumes dilution air = 0 μg Pb/m^3 and calculates 'additional' PbA;
- Pb emission rate options of 500 μg Pb/h and 1000 μg Pb/h;
- two room size options of 25 and 50 m^3;
- emission duration options of 1.5, 3 and 6 h; and
- air infiltration rate options of 0, 0.25, 0.5, 0.75 and 1.0 air volume changes per hour.

Integrating the air concentration/time curves give mean air concentrations that reflect daily use of candles. The individual trajectories of PbA over time given an emission rate of 1000 μg/h

Table 4
Average PbA concentrations over 24 h based on emission from a single candle based on emission rates of 500 and 1000 μg Pb/h

Emission rate and room size (μg/h/m^3)	Candle burning duration (h)	Air infiltration rate Air volume changes per hour (ACH)				
		0	0.25	0.5	0.75	1
		Mean PbA concentrations (μg/m^3) over 24 h				
500/50	1.5	14.5	2.5	1.2	0.8	0.6
500/50	3	28.1	5	2.5	1.7	1.2
500/50	6	52.4	9.9	5	3.3	2.5
500/25 1000/50	1.5	28.9	5	2.5	1.7	1.2
500/25 1000/50	3	56.1	9.9	5	3.3	2.5
500/25 1000/50	6	104.9	19.9	10	6.7	5
1000/25	1.5	57.8	9.9	5	3.3	2.5
1000/25	3	112.2	19.9	10	6.6	5
1000/25	6	209.2	39.7	20	13.3	10

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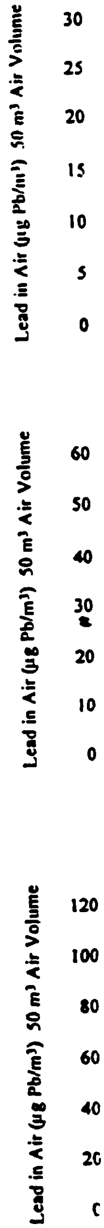

Fig. 1. T
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are summarised in Fig. 1, the resultant daily mean PbA values given an emission rate of 500 and 1000 $\mu g/h$ are also estimated (Table 4). The values of 500 and 1000 $\mu g/h$ correspond approximately to the modal mean values of 510 and 970 μg Pb/h encountered from the testing of seven candles.

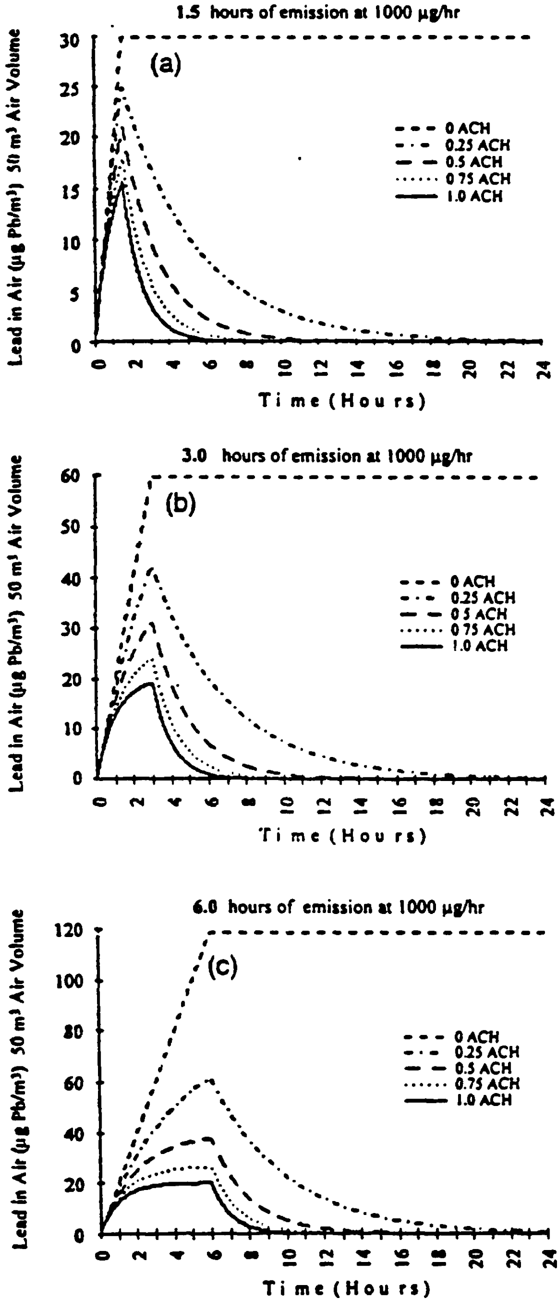

Fig. 1. Trajectories of PbA based upon room volume, emission durations of 1.5 (a), 3 (b) and 6 h (c) and a range of air infiltration options (ACH = air changes per hour) and a single source emitting Pb at 1000 μg Pb/h.

The model estimates that a candle burnt for 3 h at 1000 $\mu g/h$ in a 50-m^3 room having poor ventilation at 0.25 ACH will yield a 24-h average lead in air concentration of 9.9 $\mu g/m^3$ with a peak PbA value of 42.1 $\mu g/m^3$; for a burn duration of 6 h the PbA is an average of 19.9 and maximum of 62.1 μg Pb/m^3.

The high bioavailability of Pb carbonates is particularly well recognised owing to the previous use of such compounds in the paint industry. Lead in carbonate form (compared to metallic form) has been recognised as a poison in many instances of child Pb poisoning particularly since the 1920s to 1950s (Rabin, 1989; Silbergeld, 1997; van Alphen, 1998).

4.4. Estimating PbB based upon exposure factors and the PTWI

The Pb uptake via inhalation for hypothetical daily exposures to a mean PbA level of 5, 10 and 20 $\mu g/m^3$ (from Table 4 and Fig. 1) can be derived for 2 to 3-year-old children using exposure factors as follows:

- children from 3 to 5.9 years old have a respiration rate of 6 to 10 m^3/d (Langley and Sabordo, 1996 p. 178), assume a value of 6 m^3/d;
- the retention in the lung given fine sub-micron particle size ~35 to 50% (Langley and Sabordo, 1996 p. 179; IPCS, 1995) assume this range of values;
- the high solubility of Pb carbonate type phases [e.g. $NaPb_2(CO_3)_2OH$] assume 90% uptake of the fraction deposited in the lung; and
- children spend ~90% of the time indoors at 7 months to ~79% at 2.5 years (Brinkman et al., 1999), assume a value of 80%.

Given nominal mean continuous 24 h PbA concentrations, it is estimated that additional Pb uptake for a 2 to 3-year-old child by inhalation would be:

- 8.0 to 11.5 μg/day at PbA = 5 μg Pb/m^3;
- 16.1 to 23.0 μg/day at PbA = 10 μg Pb/m^3; and
- 32.1 to 45.9 μg/day at PbA = 20 μg Pb/m^3.

This above Pb uptake is additional to the existing exposures via food, dust, water and paint for example. They are significant exposures if they occur on a daily basis given that the PTWI (at 25 μg Pb/kg body wt.) equates with an uptake of ~18–27 μg Pb/day for a 10 to 15 kg child.

A more general calculation, sufficient for evaluating the order of magnitude of additional Pb uptakes relative to the PTWI (Table 5) is based upon a daily respiration volume of 6 m^3, a rate of deposition in the lung of 50%, a rate of uptake from lung-deposited Pb of 90%, a proportion of time spent indoors of 85%. Daily and once per week exposures scenarios are represented as a percentage of a PTWI equivalent uptake of 12.5 μg/kg of body weight for 10 and 15 kg children. The PbA values are selected from Table 4.

This calculation option does not take into account child lead exposure owing to particle deposition and subsequent child exposures.

4.5. Population-based estimates of the association between PbA and PbB

Another strategy for estimating PbB is to use the relationship between population blood lead data and outdoor PbA data (IPCS, 1995, p. 218). This relationship assumes long-term exposure. An additional exposure factor to consider is the proportion of time exposed to such PbA levels, a factor of 80% of the time indoors could be used. Where children have inhalational exposures as well as hand-to-mouth type exposures to deposited dusts, the PbB:PbA relationship predicts increases of 3 to 5 μg Pb/dl for every 1.0 μg Pb/m^3 in air (Brunekreef, 1984; IPCS, 1995).

Given this association, and a long-term PbA of 5.0 μg Pb/m^3, child PbB may be expected to rise an additional 12 to 20 μg/dl; at a PbA of 9.9 μg Pb/m^3 child PbB may be expected to rise an additional 24 to 40 μg/dl. Other individual scenarios can readily be calculated. Clearly on the basis of regular daily burning of candles having Pb core wicks there are unacceptable risks. One candle burning episode per week and average PbA at one-seventh of 5.0 μg Pb/m^3 (0.71) and one-seventh of 9.9 μg Pb/m^3 (1.41) can be calculated to give rise to PbB of 1.7–2.9 μg/dl to 3.4–5.7 μg/dl. Such additional Pb exposures have the ability to raise PbB above 10 μg/dl, which is currently a target level that children should not exceed.

4.6. Indoor / outdoor ratios in PbA and child exposure to air emission sources located indoors

The relationship between the PbB of popula-

Table 5
Percentage of the PTWI for Pb and children at 10 and 15 kg that will be attributed to PbA (based upon candle burning events) at 1.2–104.9 μg Pb/m^3, daily and once per week exposures

Mean indoor PbA over 24 h (μg Pb/m^3)	Percentage of the 'PTWI equivalent' attributable to indoor PbA			
	Calculation based on a 10 kg child		Calculation based on a 15 kg child	
	Daily exposure (~% of PTWI)	Exposed 1 day per week (~% of PTWI)	Daily exposure (~% of PTWI)	Exposed 1 day per week (~% of PTWI)
1.2	15.4	2.2	10.3	1.5
2.5	32.1	4.6	21.4	3.1
5	64.3	9.2	42.8	6.1
9.9	127.2	18.2	84.8	12.1
19.9	255.8	36.5	170.5	24.4
39.7	510.2	72.9	340.1	48.6
104.9	1348.2	192.6	898.8	128.4

tions of young children and outdoor average ambient PbA concentrations (Brunekreef, 1984; IPCS, 1995) may not be applicable to indoor Pb emission-based exposures of children for the following reasons:

- indoor air typically has air Pb concentrations of 30 to 80% of outdoor air (Kutlaca, 1998);
- children spend 79 to 90% of their time indoors (Brinkman et al., 1999); and
- elevated deposition occurs in close proximity to sources (Chamberlain et al., 1979) whether indoor or outdoor.

The PbB:PbA relationship of 3 to 5 μg Pb/dl for every 1.0 μg Pb/m^3 will understate the Pb exposure of young children where they live in a house where there is a potent, close-proximity indoor air Pb source and indoor deposition in the immediate vicinity of that indoor source. A cautious initial approach in the absence of additional information may be to assume a safety factor of two such that the PbB:PbA relationship for an indoor Pb emission source is 6–10 μg Pb/dl for every 1.0 μg Pb/m^3.

Given continuous PbA levels of 5.0 μg Pb/m^3, and 9.9 μg Pb/m^3 (and exposure for 80% of the time) child PbB may be expected to rise an additional 24 to 40 μg/dl and 47 to 79 μg/dl, respectively. For the 1-day per week candle burning episode scenario producing a long-term PbA at one-seventh of the PbA values of 5.0 μg Pb/m^3, and 9.9 μg Pb/m^3, (0.71 and 1.41 μg Pb/m^3) this is estimated to give rise to a PbB of 3.4–5.7 μg/dl to 6.8–11.3 μg/dl.

4.7. *Deposition of Pb particles in the home over the long-term*

A single 38 cm long candle can emit ~104 000 μg Pb into the air. The deposition of as little as 5 to 10% of that Pb onto the floor of a 5×5 m room would result in a floor Pb loading of ~150 to 300 μg/m^2. Such a floor Pb loading would readily be associated with elevations in child blood lead (Battelle, 1998). With long-term burning of candles with Pb metal wick cores indoors, it is suggested that deposited Pb may in the longer-term be a significant and ongoing source of child Pb exposure.

4.8. *Uncertainties in risk assessment*

Potential variation in candle emission rates have already been raised, basic factors such as the composition of the metal wick core, metal core diameter and candle burning rate may vary between candles used. Individual Pb exposures will be highly dependant on the rate of candle emission, emission particle size, number of candles burnt, room volume, duration of candle burning, frequency of candle burning, the time spent in the home and the ventilation status of the home. Factors such as whether the individual is exercising heavily or at sleep, or whether they are in close proximity to an emission source and any vertical stratification of Pb emissions within rooms may influence individual exposures.

5. Conclusions

A candle with a wick having a core of Pb metal can transfer large quantities of Pb into the air in the form of sub-micron particles of a sodium lead carbonate hydroxide compound that is likely to be highly biologically available.

Two risk assessment calculation strategies have been used. One used exposure factors and comparison to an uptake equivalent to the PTWI, the other refers to a population-based association between PbB and outdoor PbA. Both calculation methods readily predict high Pb uptakes and elevated child PbB, respectively, over a range of exposure settings. The PTWI methodology using exposure factors appears to understate Pb exposure relative to the method using the population associations between PbB and outdoor PbA. Some detailed evaluation of exposure factors, particularly in relation to the proportion of Pb deposited in the lung may be warranted; similarly the effect of PbA in determining Pb in dusts and other associated exposure routes may be important reasons for apparent discrepancies.

The risks associated with the candles having Pb core wicks to young children are likely to be significant due to both inhalational exposure and other subsequent exposures to any deposited particles in household dusts. There is the potential for entire families to have high Pb exposures because of such a Pb source. Where multiple Pb metal wick core candles are burnt on a regular basis, for periods of > 3 to 6 h, in poorly ventilated settings extreme levels of Pb exposure are possible. Clinical child Pb poisonings and death could be predicted where multiple candles are burnt on a daily basis in such settings. Where candles are burnt once per week for several hours at a time, average weekly lead in air levels in typical houses will be such that additional child Pb uptakes could drive PbB levels over 10 μg/dl.

A single candle emitting 1000 μg Pb/h burnt for 3 h in a 50-m^3 room having poor ventilation at 0.25 is estimated to yield a 24-h average lead in air concentration of 9.9 μg/m^3 (Table 4) with a peak PbA value of 42.1 μg/m^3. Daily burning of one candle in this manner is estimated to elevate child PbB by a minimum of 24–40 μg/dl based on the PbB:PbA relationship of Brunekreef (1984) once per week burning scenario is estimated to elevate PbB by 3.4 to 5.6 μg/dl.

An additional safety factor of 2 is suggested in PbB estimates using the PbB:PbA ratio due to emissions being located indoors. These candles having a Pb wick core have the potential for highly unacceptable health risks and would contravene consumer protection, poisons and public health regulations of many jurisdictions.

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TAB B

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: NOV 15 2000

TO : Mary Ann Danello, Ph.D., Associate Executive Director, Directorate for Health Sciences

THROUGH : Lori E. Saltzman, M.S., Director, Division of Health Sciences, Directorate for Health Sciences

FROM : Kristina M. Hatlelid, PhD., M.P.H., Toxicologist, Division of Health Sciences

SUBJECT : Review of Lead Emissions from Candles

Introduction

Some candles available to consumers contain wicks with metal cores. The metal is intended to provide certain performance characteristics to the wick as the candle is made and as it burns. Some of these metal wicks contain lead, which can be released into the air during candle burning. Some of the emitted lead may also deposit onto surfaces in the room. This deposited lead could remain accessible to a child for an extended period of time, where exposures could occur through direct mouthing of surfaces or objects or by hand-to-mouth contact.

The adverse health effects of lead exposure in children are well-documented and may have long-lasting or permanent consequences. These effects include neurological damage, delayed mental and physical development, attention and learning deficiencies, and hearing problems. Because lead accumulates in the body, even exposures to small amounts of lead can contribute to the overall level of lead in the blood and to the subsequent risk of adverse health effects. The scientific community generally recognizes a level of 10 micrograms of lead per deciliter of blood (10 μg/dL) as a threshold level of concern with respect to lead poisoning (CDC, 1997). To avoid exceeding that level, young children should not chronically ingest more than 15 micrograms of lead per day (15 μg/day) from consumer products (CPSC, 1998). The staff uses 15 to 30 days to represent a chronic exposure time period.

Analysis of Lead Emissions from Candles

CPSC Analysis

The CPSC Directorate for Laboratory Sciences Division of Chemistry (LSC) analyzed 23 candles with metal core wicks purchased from stores in the Washington, D.C. area and across the U.S. (CPSC, 2000). Inductively coupled plasma spectroscopy (ICP) was used to analyze the metal content of wicks after digestion in concentrated nitric acid. Five of the metal cores consisted of 86% to >99% lead by weight. Another five cores consisted of >99% zinc with 0.01-0.06% lead and 11 cores were >99% zinc with no detectable lead (limit of detection, 0.003%).

The emission of lead during candle burning was determined using a small-chamber setup with a water-jacketed column gas scrubber packed with dilute nitric acid-wetted glass wool with subsequent analysis by ICP. The small-chamber testing for lead emissions during the burning of four of these candles resulted in lead releases ranging from below the limit of detection (25 µg/hour) to approximately 267 µg/hour.

Public Citizen Petition

Public Citizen surveyed 285 candles from 12 stores in the Baltimore-Washington, DC area. They found nine candles (3% of the total sample) that had wicks containing between 33% and 85% lead by weight. The total lead content of wicks ranged from 24,000 to 118,000 µg. They did not conduct testing to determine the amount of lead that would be emitted from each candle when burned.

van Alphen (1999)

Van Alphen tested seven samples of lead-cored wick candles sold in Adelaide, South Australia. The candles were 38 cm tall and from 4.8 cm wide at the top of the candle to 5.5 cm wide at the base. The wicks contained approximately 95-99% lead by weight. Lead emissions during candle burning were determined using a small-chamber setup with glass fiber filters with subsequent extraction with nitric acid and analysis by flame atomic absorption. Lead emissions from burning candles ranged from 450 to 1130 µg/hour. These candles burned at rates from 0.2 to 0.42 cm/hour. The candles emitted approximately 8 to 33% of the lead in the wick, with an estimated average release of 104,000 µg lead during burning of the entire candle over approximately 127 hours.

Krause (1999)

As part of his master's thesis work, Krause collected candles from stores in Florida. Of the 91 candles tested, 27 had wire core wicks. Two of the candles with wire core wicks were reported to contain 22% and 32% lead by graphite furnace atomic absorption spectroscopy (AA); the lead content of the other wicks was not determined. The emission of lead during candle burning was determined using a small-chamber setup with glass fiber filters with subsequent extraction with nitric acid and analysis by AA or ICP. Four of the 27 candles with wire core wicks emitted detectable quantities of lead, ranging from 6 µg/hour to 2,200 µg/hour. One candle in a metal container emitted 24 µg/hour (this candle did not have a wire core wick).

Nriagu and Kim (2000)

Nriagu and Kim tested several candles from the United States, Mexico, and China for lead emissions when burned. They did not measure the lead content of the wicks. Using a small chamber test with a nitric acid trap and subsequent analysis by graphite furnace atomic absorption spectroscopy, lead releases from burning candles ranged from 0.5 to 327 µg/hour.

Emissions Estimates and Exposure and Risk Assessments

CPSC staff and other researchers have shown that candles containing lead-cored wicks may emit relatively large amounts of lead into the air during candle burning. Candles analyzed by CPSC and other researchers emitted lead up to 2,200 µg/hour during burning.

Using a standard indoor air model, a candle burning for 4 hours/day, emitting lead at 2,200 µg/hour in a 51 m^3 room with 0.5 air changes/hour would result in an average air lead level of 14.2 µg/m^3 (Appendix I). The air lead concentrations resulting from burning lead-cored wick candles depend on factors such as room size and air exchange rate. A discussion of these parameters may be found below in the section *Limitations and Other Considerations*.

CPSC Exposure Analysis

To prevent children from exceeding the 10 µg/dl blood lead level (BLL) of concern, CPSC staff seeks to limit chronic ingestion of lead to less than 15 µg of lead per day from consumer products. The staff uses 15 to 30 days to represent a chronic exposure time period.

Lead may be absorbed into the body whether it is ingested or inhaled. Once particles are deposited in the lower respiratory tract, particulate lead is almost completely absorbed. All chemical forms appear to be absorbed. The rate of respiratory tract deposition of particulate airborne lead is modified by factors including particle size and ventilation rate, but it is estimated to be about 30-50% in adult humans (USEPA, 1986).

Since 30-50% of inhaled particulate lead is deposited in the lung and absorbed into the body and 30-50% of ingested lead is absorbed into the body (reviewed by ATSDR, 1999), the bioavailability of lead from inhalation is similar to the bioavailability of lead from ingestion. Therefore, a 15 µg/day intake by inhalation of airborne lead can be assumed to have a similar contribution to BLL as a 15 µg/day intake from ingestion of lead, assuming the 15-30 day chronic exposure time period.

One- to two-year-old children breathe at an average rate of 6.8 m^3/day (USEPA, 1997). Assuming children are in the room 80% of the day, the 15 µg/day intake by inhalation would be reached if the 24-hour average lead concentration in air were about 2.8 µg/m^3. Using a standard air concentration model and assuming a closed, 15 ft. by 15 ft. room with an 8 ft. ceiling (51 m^3) with 0.5 air exchanges per hour, a candle burning for 4 hours/day for 15-30 days would contribute to excess lead exposure for children in the room (*i.e.*, 15 µg/day) if it emitted 430 µg lead per hour.

Although the analyses by CPSC and other researchers showed that lead emissions rates from candles are highly variable, the results indicate that some lead-cored wick candles do emit lead at rates greater than 430 µg/hour.

Other Analyses

Public Citizen did not conduct testing to determine the amount of lead that would be emitted from each candle when burned. By making a series of assumptions, they calculated the air lead levels from the total amount of lead in the wick. They assumed the wick is consumed at a rate of 2 cm/hour, 20% of the lead in the consumed wick is emitted, the candle burns for 3 hours/day in a 51 m^3 room, and the room ventilation rate is 0.20 per hour.

Using a standard mathematical air concentration model and this set of assumptions, they calculated that the average 24-hour air lead levels in the room from burning these candles